PARASITOLOGY

CAMBRIDGE UNIVERSITY PRESS
London: FETTER LANE, E.C.
C. F. CLAY, Manager

Edinburgh: 100, PRINCES STREET
London: H. K. LEWIS AND CO., Ltd., 136, GOWER STREET, W.C.
WILLIAM WESLEY AND SON, 28, ESSEX STREET, STRAND
Chicago: THE UNIVERSITY OF CHICAGO PRESS
Bombay, Calcutta and Madras: MACMILLAN AND CO., Ltd.
Toronto: J. M. DENT AND SONS, Ltd.
Tokyo: THE MARUZEN-KABUSHIKI-KAISHA

PARASITOLOGY

EDITED BY

GEORGE H. F. NUTTALL, F.R.S.
Quick Professor of Biology in the University of Cambridge

ASSISTED BY

EDWARD HINDLE, PH.D.

Volume VIII 1915–16

Cambridge:
at the University Press
1916

CONTENTS

No. 1 (June).

No. 2 (September).

No. 3 (January).

No. 4 (June).

Vol. 8, No. 1 June, 1915

PARASITOLOGY

EDITED BY

GEORGE H. F. NUTTALL, F.R.S.
Quick Professor of Biology in the University of Cambridge

ASSISTED BY

EDWARD HINDLE, Ph.D.

CAMBRIDGE UNIVERSITY PRESS
C. F. CLAY, Manager
LONDON: FETTER LANE, E.C.
EDINBURGH: 100, PRINCES STREET
ALSO
H. K. LEWIS, GOWER STREET
WILLIAM WESLEY AND SON, 28, ESSEX STREET, STRAND
CHICAGO: THE UNIVERSITY OF CHICAGO PRESS
BOMBAY, CALCUTTA AND MADRAS: MACMILLAN & CO., LTD.
TORONTO: J. M. DENT AND SONS, LTD.
TOKYO: THE MARUZEN-KABUSHIKI-KAISHA

Price Ten Shillings net

[*Issued June* 25, 1915]

THE UNIVERSITY OF CHICAGO SCIENCE SERIES

This series recently established by the Trustees of the University owes its origin to a feeling that there should be a medium of publication occupying a position between the technical journals, with their short articles, and the elaborate treatises which attempt to cover several or all aspects of a wide field. The volumes of the series will differ from the discussions generally appearing in technical journals in that they will present the complete results of an experiment or series of investigations which have previously appeared only in scattered articles, if published at all. On the other hand they will differ from detailed treatises by confining themselves to specific problems of current interest and in presenting the subject in as summary a manner and with as little technical detail as is consistent with sound method. They will be written not only for the specialist but also for the educated layman. The size of the volumes will range from fifty to one hundred and fifty pages.

THE FIRST PUBLISHED VOLUME OF THE SERIES

The Evolution of Sex in Plants. By John Merle Coulter, Head of the Department of Botany in the University of Chicago. viii + 140 pages, small 12mo, cloth; 4*s.* net.

In this first volume of the new "University of Chicago Science Series" Professor Coulter, the editor of the *Botanical Gazette* and the author of numerous volumes on botanical science, has given a presentation of the results of research showing that all reproduction is the same in its essential features and all methods of reproduction are natural responses to the varying conditions encountered by plants in their life histories. Sex reproduction, the author says, is simply one kind of response, the sex feature not being essential to reproduction, but securing something in connection with the process. Various phases of the subject discussed include the evolution of sex organs, the alternation of generations, the differentiation of sexual individuals, and parthenogenesis. The last chapter, which offers a theory of sex, reviews the more prominent facts set forth in preceding parts of the volume, and serves both as a summary and a working hypothesis.

OTHER VOLUMES IN PREPARATION FOR EARLY PUBLICATION

The Origin of the Earth. By Thomas C. Chamberlin, Head of the Department of Geology in the University of Chicago.

The Isolation and Measurement of the Electron. By Robert Andrews Millikan, Professor of Physics in the University of Chicago.

Finite Collineation Groups. By Hans F. Blichfeldt, Professor of Mathematics in Leland Stanford Junior University.

OTHER VOLUMES PLANNED AND IN PREPARATION

The Evolution of Reptiles. By Samuel Wendell Williston.

Food Poisoning. By Edwin Oakes Jordan.

The Problem of Individuality in Organisms. By Charles Manning Child.

The Development of a New System of Organic Chemistry, Based on Dissociation Concepts. By John Ulric Nef, with the co-operation of J. W. E. Glattfeld.

The Living Cycads. By Charles Joseph Chamberlain.

Mechanics of Delayed Germination in Seeds. By William Crocker.

The Rigidity of the Earth and of Materials. By Albert A. Michelson.

The Problem of Fertilization. By Frank R. Lillie.

Linear Integral Equations in General Analysis. By Eliakim Hastings Moore.

The University of Chicago Press

The Cambridge University Press
Agents for the British Empire
London, Fetter Lane

VOLUME VIII JUNE, 1915 No. 1

GANYMEDES CRATERE N.G. ET S.

BY W. HAROLD LEIGH-SHARPE, B.Sc., A.C.P.,
Demonstrator in Biology at Guy's Hospital Medical School, London.

(With 6 Text-figures.)

MY interest having been aroused in *Calliobdella lophii*[1], I requested all my friends engaged upon the sea to keep a look-out for any leeches that might come to hand and especially for *Calliobdella*. Accordingly on 6. VIII. 1914 I received a specimen of a leech, taken near St Margaret's Hope towards the north-east of S. Ronaldsay in the Isles of Orkney, which as far as I can discover has never been described before, and which presents peculiar and interesting features not wholly dissimilar from those of *Calliobdella*. I propose to name the leech *Ganymedes* (or, if this name should be pre-occupied, *Ganymedebdella*) *cratere*.

The leech reached me in a moribund condition, and died shortly afterwards, it having been captured towards the end of July, and its despatch to me having been hindered owing to the outbreak of the war.

Habitat. This marine leech, a member of the Rhynchobdellidae, or jawless leeches, and belonging to the family Ichthyobdellidae, was parasitic upon a fish "with a pronounced anal papilla." After some written discussion with the collector, I have, after careful consideration, decided that this fish was an immature male specimen of *Callionymus lyra* about 12 cm. long, some doubt having at first arisen because it is the uro-genital and not anal papilla that is so pronounced in *Callionymus*. Assuming that the collector did not mistake the apertures of the fish I am now of the opinion that the anal papilla was an artefact produced by the adhesion round the anus of the host of the leech's anterior sucker which is furnished with a most powerful muscular rim for the

---

[1] Leigh-Sharpe (1914), *Calliobdella lophii*, *Parasitology*, VII. 204, also (1913), *Calliobdella lophii*, *Journ. Mar. Biol. Assoc.* X. 81.

purpose (described below, see also Figs. 1 and 2), causing a constriction on the body of the host proximal to the anus. The leech appears to be a stationary parasite not quitting the papilla that it has induced; it is conceivable that it may be a faecal feeder.

Since in my paper on *Calliobdella lophii* (*loc. cit.*) I gave, as one of the reasons for believing the latter leech to be a stationary parasite, the fact that four or five specimens were found together on one host, hence rendering fertilization possible, I was at first at a loss to perceive how fertilization could be effected in *Ganymedes cratere*. This gives the clue to the second reason for believing the host to be *Callionymus lyra* for in this fish, practically alone, although there is no actual copulation, there is a courtship, and a pairing or mating which has been admirably described at length by Holt[1]. Pending the mating of the fishes, I believe the leeches are able to copulate; during this process I consider one of the leeches is practically bound to be detached from its host, and probably perishes. If, however, the other leech lays many eggs that are fertile the balance in nature is maintained. Owing to the anal papilla being so prominent, by contrast the uro-genital papilla seems not so prominent, or perhaps its size actually has been diminished by the superabundant growth of the former.

(It would be interesting to discover if there is any pairing or courtship in *Lophius piscatorius* which could be utilised by *Calliobdella lophii.*)

Body. The leech is divided into two distinct regions, a neck region which is short and bare, and a body or abdomen, the latter carrying laterally rounded vesicles described below. The animal is circular in section in the neck and in the short anal region, but in the abdominal region it is greatly flattened dorso-ventrally, so that the animal, taken as a whole, presents the outline of a minute vase. The length when living was 0·8 cm., and this seemed to me a normal measurement, for the leech appeared incapable of any appreciable extension when alive, and did not exhibit contraction to any extent when dead. The colour is brown ochre, the suckers being paler, and the abdomen darker; the whole gradation of tints resembling those met with in the brown alga *Fucus*. There are no special coloration characteristics, nor papillae, except one papilla hereinafter mentioned.

Suckers. As is usual with leeches there are two suckers, one at either extremity of the body. The anterior sucker is crateriform, surrounds the mouth, and is characterized by its great size, being nearly as broad as the maximum width of the abdomen and over four times the size of the posterior sucker, this being the reverse of what obtains in *Calliobdella lophii*. The anterior sucker is surrounded by a thick

---

[1] Holt (19. IV. 1898), *Proc. Zool. Soc.* p. 281.

muscular rim (Fig. 1 *r.*) which grips the anal papilla of the host like an elastic band. From the rim to the mouth, in the hollow of the crater pass five muscular bands, arranged in the circle at equal distances from one another; these muscles, when they contract, no doubt bring the mouth of the leech into contact with the anus of the host, and perhaps indirectly increase the pressure of the muscles of the rim. The mouth is slit-like (not circular), the single muscle band being on the *dorsal* side, whilst two bands are lateral and two are ventro-lateral. It was observed by the collector that the leech was attached to the anal papilla of the fish in such a way that the *dorsal side of the sucker was towards the right side of the host.* The leech, which, when the host is at rest, I presume, hangs vertically downwards, is therefore dragged through the water on its side, and cuts the water with the narrow edge of its abdomen. The shortness of the leech's neck, however, will prevent its being bent far in a backward direction.

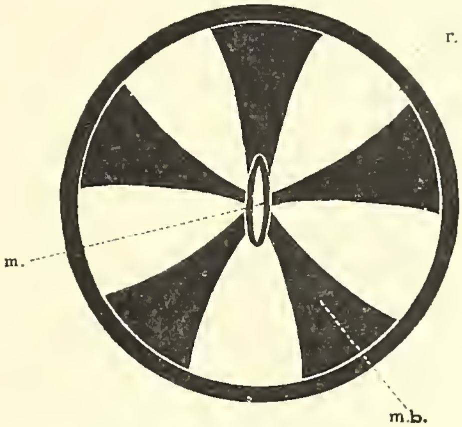


Fig. 1. *Ganymedes cratere.* The anterior sucker in frontal aspect, with the dorsal side to the top of the diagram. *m.* mouth; *m.b.* five muscle bands; *r.* muscular rim.

The large size of the anterior sucker is explained by the facts: (1) that the leech by means of the muscular rim gives rise to an abnormal anal papilla on the host to which it remains permanently attached, and (2) that the sucker may act as a food reservoir, if the host's faeces are discharged in greater quantity than the leech can immediately ingest, *i.e.* supposing the leech to be a faecal feeder.

The suckers are only a shade paler than the rest of the body. The posterior sucker is almost functionless, presumably from disuse, the depression therein being exceedingly shallow. Admitting that the leech, as I saw it, was in a dying condition, yet it made no attempt to use the posterior sucker, but held on the cork of the tube it travelled in, and afterwards to the side of the containing jar with its anterior sucker, never using the posterior sucker even when irritated into letting go anteriorly.

Segmentation (consult Fig. 2).

(*a*) *Neck.* A. HEAD:

(*a*) *Anterior sucker* .. .. (?) **6** segments.

(*b*) A portion of the anterior sucker which is apparently post-oral, and which, though not showing external annulation, probably represents morphologically the three small rings in a similar position in *Calliobdella lophii* .. .. (?) **3** segments.

B. PRECLITELLUM .. .. **3** segments.

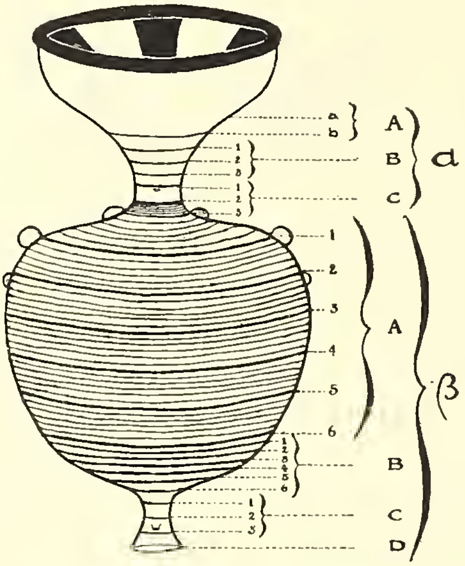


Fig. 2. *Ganymedes cratere* in ventral aspect, showing segmentations and annulations. Numbering and lettering explained in the text.

The clitellum is divided from the preclitellum by a deep furrow which shows as a very marked line in a preparation cleared in creosote, viewed under the microscope as a transparent object.

C. CLITELLUM .. .. **3** segments.

The clitellum exactly resembles that of *Calliobdella lophii.* The first two segments are large, the second being the larger of the two, and neither is divided by furrows into annuli. The ♂ genital aperture is between these two segments, or rather towards the anterior border of the second. The third segment is intermediate in size between the first and second, and is divided into six minute annuli.

The ♀ genital aperture is on the first annulus of the third segment.

I do *not* find any lateral tubercles on the neck whether respiratory or otherwise.

(β) *Abdomen.* A. TESTIS REGION .. .. **6** segments.

Each of the first six segments of the abdomen is completely divided into six annuli. The first three only, of these six segments, bear lateral respiratory vesicles, bordering the first two annuli of these segments. There is one pair of testes to each of these segments. Each *segment* (not annulus) is divided from the next by a deep furrow which shows as a marked line when treated and viewed as above.

B. CAECUM REGION .. .. **6** segments.

These six segments are small, and each is only equal in size to an annulus of the preceding segments of the testis region. Though the caeca actually start about the boundary between segments 4 and 5 of the testis region, and only extend as far as the boundary of the 3rd and 4th segments of this region, yet no testes are found here.

C. ANAL REGION .. .. **3** segments.

The anus opens dorsally between the ultimate and penultimate segments. Ventrally, in the middle of the ultimate segment there is a raised glandular papilla, of possible olfactory function, shown on an enlarged scale in Fig. 3.

D. POSTERIOR SUCKER .. .. (?) **7** segments.

Total for the whole body **37** segments. (See Fig. 2.)

Nervous system. There occurs the usual ventral nerve cord with ganglia along the chain. The foregoing conclusions concerning segmentation are based on a consideration of these ganglia in agreement with the views of Leuckart and Whitman given in my previous paper (*q.v.*).

Respiration. Respiration is carried on by means of hemispherical vesicles protruding from the sides of the abdominal portion of the body. These vesicles rise and fall. They are reduced in number from the condition prevailing in *Calliobdella*, *Piscicola*, *Cystibranchus*, *Branchellion*, and other genera, there being only *three* pairs, situated on either side of the first three segments of the abdomen bordering the first two annuli of each segment.

The second pair is *much* the largest in size. The third pair is small, and though perhaps not functionless, may be regarded as vestigial; they alone did not seem to pulsate; I can offer no explanation as to the cause of their reduction. The vesicles are pale in colour, in fact almost white.

Pigment. Under the epidermis are found large clear pigment cells with brownish contents, similar to those found in *Calliobdella lophii.*

Sense Organs. There are no eyes.

On the third of the three segments of the anal region in the middle of the ventral surface is a large papilla about one-third as broad at its summit as the segment on which it is borne and from which it projects posteriorly (Fig. 3). Its summit is flat and elliptical, and has no definite apertures. The papilla is found to consist of soft spongy tissue, among which are seen groups of elliptical cells with elongated nuclei, packed round one another, and resembling in section the coats of an onion, recalling the structure of a Pacinian corpuscle, or the taste buds of the circumvallate papillae of the mammalian tongue, or the so-called chromophilous "gland" of *Tomopteris* (which I maintain is sensory in function). I will not go so far as to say these cells have cilia projecting freely from the flat summit of the papilla, though it seems to me not unlikely. I consider that the function of these cells is olfactory or gustatory.

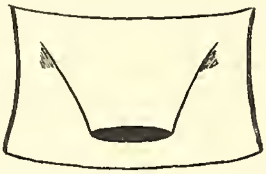


Fig. 3. *Ganymedes cratere.* Mid-ventral papilla on the third segment of the anal region (much enlarged).

Digestive System. The mouth is elliptical in outline and situated in the centre of the anterior sucker. When shut it forms a longitudinal slit. The anus opens dorsally between the second and third segments of the anal region. There is an oesophageal bulb or pharynx with thick muscular walls. The pharyngeal sheath is reduced in length. To the best of my belief salivary glands are present, but I am not sure; there appear to be slight traces of glandular tissue in the position where one would expect salivary glands to be. The stomach is the longest part of the alimentary canal (Fig. 4). As is usual in leeches, caeca are present, and herein is exhibited a marked contrast to the condition in *Calliobdella,* for the primitive condition of a pair of widely divergent caeca obtains, instead of the specialized reduction to one caecum found in the other genus. The retention of this primitive character in so specialized a leech as *Ganymedes* may be correlated with the fact that it is a faecal feeder; the ingested matter having to be retained in the digestive tract for a longer period in order that it may be better assimilated. The caeca leave the stomach at the boundary of the 4th and 5th segments of the testis region and extend to the boundary of the 3rd and 4th segments of the caecum region. They appear crenated, and both caeca were full of contents in my specimen. The intestine is relatively long and is in straight continuation with the stomach, the caeca being disposed laterally with regard to it.

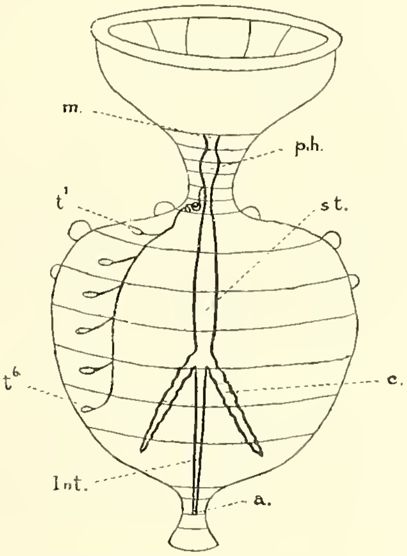


Fig. 4. *Ganymedes cratere.* Digestive system in dorsal aspect; the reproductive system being shown on the left side only. *m.* mouth; *ph.* pharynx; *st.* stomach; *c.* caeca; *Int.* intestine; *a.* anus; $t.^1$, $t.^6$ the first and last testes of that side respectively.

Coelom. The divisions of the body cavity are best seen from Fig. 5. The condition is precisely the same as in *Calliobdella.* There is a ventral sinus, a dorsal sinus, two lateral sinuses, and an intestinal sinus. The ventral nerve cord is within the ventral sinus.

Reproductive system. The generative organs are situated at the base of the neck. The position of the genital openings on the clitellum has already been stated.

The *male* reproductive organs consist of six pairs of metameric testes, situated respectively in the middle of the first six segments of the abdomen, as is usual in the Ichthyobdellidae (except *Abranchus*). The testes lie in the 3rd and 4th annuli of the segment (Fig. 4). From each testis, as is usual, proceeds a small duct, the vas efferens; there being as many vasa efferentia as there are testes. From the posterior testis on each side the vas efferens passes inwards and upwards immediately into the vas deferens which in its course receives the remaining vasa efferentia. The vasa deferentia run some distance from the testes. In the posterior part of the clitellum each vas deferens takes on many curves and sinuosities, as it does in *Calliobdella*, and slightly in *Piscicola*, while in most genera (according to Johannson) it is perfectly straight. About the male genital aperture the vasa deferentia open out into ductus ejaculatorii which are not of very large size, and which open separately into a bursa of small dimensions which communicates with the exterior by the male genital aperture. The forward-directed portion of the saccular bursa, as is usual in leeches, is developed so as to form a penis or copulatory organ capable of being protruded through the male genital aperture. The penis is conical, but does not include the ductus ejaculatorii. I have no information to offer as to whether spermatophores are formed. Vesiculae seminales are not present. The condition of the penis and bursa resembles that of the more primitive of the Ichthyobdellidae. The *female* reproductive organs consist of a pair of ovaries which occupy the major portion of the second segment of the abdomen. A short duct proceeds from the anterior end of each ovary which quickly unites with its fellow to form an oviduct (Fig. 6).

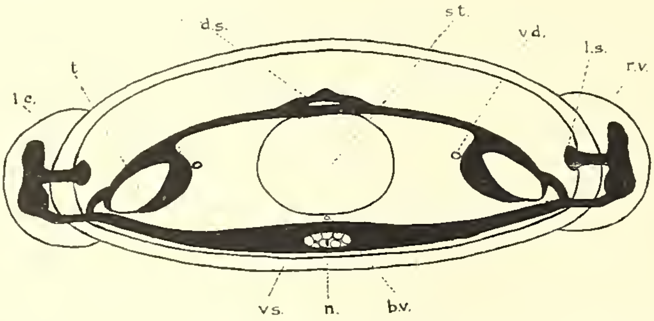


Fig. 5. *Ganymedes cratere.* Cross section of the animal in the region of the second abdominal segment. Diagrammatic, since the respiratory vesicles and the testes would not actually show in the same section as is obvious from Fig. 4. *d.s.* dorsal sinus; *v.s.* ventral sinus; *l.s.* lateral sinuses; *r.v.* respiratory vesicle; *l.c.* lymph cavity; *st.* stomach; *n.* ventral nerve cord ganglion; *b.v.* blood vessel; *v.d.* vasa deferentia; *t.* testes.

The circumstances under which fertilization may be effected have already been discussed.

The characters which indicate that Ganymedes cratere *is a stationary parasite are:* (1) its peculiar attachment to anal papilla of host by means of an enormously developed anterior sucker; (2) the weak development of longitudinal muscle layer; (3) the shallowness of the posterior sucker; (4) the rarity of the leech.

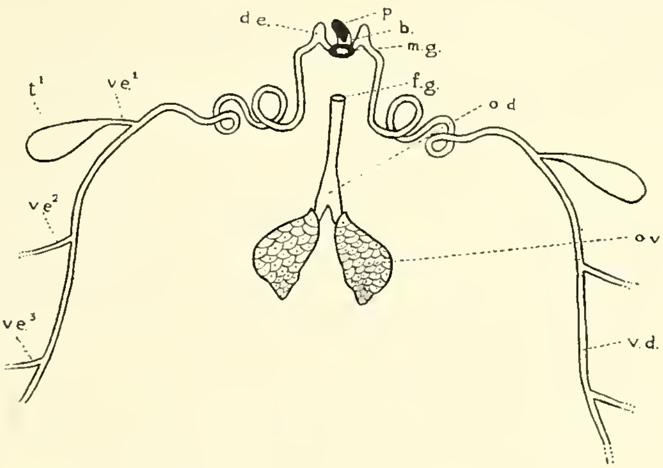


Fig. 6. *Ganymedes cratere.* General scheme of the reproductive system. *p.* penis; *b.* bursa; *d.e.* ductus ejaculatorii; *m.g.* male genital aperture; *f.g.* female genital aperture; t^1. the first pair of testes; $v.e.^1$, $v.e.^2$, $v.e.^3$ the first three pairs of vasa efferentia; *v.d.* vasa deferentia; *od.* oviduct; *ov.* ovary.

Calliobdella lophii *and* Ganymedes cratere *resemble each other in the following main characters:*

(1) The great development of *one* sucker; (2) the general agreement as to segmentation; (3) the similar positions of genital apertures and anus; (4) the presence of respiratory vesicles; (5) the coiled vas deferens in clitellum; (6) the absence of eyes; (7) the typical (or "complete") abdominal segment of six annuli; (8) the absence of blackish-brown star-shaped pigment cells; (9) nerve cord within the ventral sinus; (10) similar divisions of the coelomic sinuses; (11) both species are probably stationary parasites upon a single host.

Summary of the principal differences between Calliobdella lophii *and* Ganymedes cratere.

CALLIOBDELLA LOPHII.	*GANYMEDES CRATERE.*
Posterior sucker well developed without a thickened rim.	Anterior sucker well developed with a thickened rim and 5 muscular bands.
1 caecum.	2 caeca.
Vesiculae seminales *present*.	*No* vesiculae seminales.
Respiratory vesicles 11 pairs.	Respiratory vesicles 3 pairs.
Undifferentiated abdomen.	Abdomen divided into: (1) a Testis region with 6 annuli to a segment. (2) a Caecum region with 1 annulus to a segment.
Neck of 11 annuli.	Neck reduced to 3 annuli.
Slight dorsi-ventral flattening.	Pronounced dorsi-ventral flattening.
No gustatory papilla.	Gustatory papilla in anal region.
Vas deferens situated external to (*i.e.* on the body wall side of) the testes.	Vas deferens situated internal to (*i.e.* on the stomach side of) the testes.

Generic characters. A leech divided in a very marked manner into a short neck, and a very flattened abdomen. Each "complete" segment of the abdomen consists of six annuli, but only the first six are so divided. Along the side of the abdomen are *three* pairs of respiratory vesicles. Two caeca. No vesiculae seminales. Blackish-brown star-shaped pigment cells are not present. There is no special development of the reproductive system.

Specific characters. It is difficult in a hitherto unknown animal to decide which characters are generic and which specific. The following points are probably of only specific value: host, *Callionymus lyra* (?). Anterior sucker over four times the size of the posterior with a muscular rim and five muscular bands. The last segment of the anal region bears ventrally a sensory papilla. No eyes[1].

I am indebted to Messrs T. J. Evans and T. Reed of Guy's Hospital Medical School for affording me facilities for my investigations; to C. C. L. for sending me the leech; to Mr J. T. Cunningham of the South-Western Polytechnic, Chelsea, London, S.W., for his ever kind and valuable help; and to Mr Harold R. Southam for reproducing the drawings from my rough sketches.

---

[1] I now consider the presence or absence of eyes of specific and not of generic value as in my previous paper (*loc. cit.*). Thus we have in the genus *Platybdella*, *P. quadrioculata* with four eyes and *P. anarrhichae* without eyes; and others.

A NOTE ON THE VARIABILITY IN SIZE OF *AMBLYOMMA HEBRAEUM* KOCH.

By L. E. ROBINSON, A.R.C.Sc. Lond.

(*From the Cooper Laboratory for Economic Research, Watford.*)

(With 3 Text-figures.)

Variability in the size and, in a lesser degree, the taxonomic features of male ticks, has arrested the attention of all who have had occasion to examine moderately large numbers of examples of the same species. In the case of the female tick, this variability, though doubtless coextensive with that of the male, is more or less obscured by the wide range of variation in size, depending upon the degree of engorgement; and, also, by the fact that in the female tick the taxonomic characters are, as a rule, less pronounced. The present note is only concerned with variability in the size of the male.

The earliest allusion to this subject, in the published literature on ticks, is that of Aragão (1911), who, in the introduction to his paper on the ticks of Brazil, condemned Neumann's then recently-described variety of *Amblyomma cajennense-parviscutatum*, on the grounds that he had observed the appearance of the *parviscutatum* form among the progeny of typical females of *A. cajennense*. He also noticed that such varieties could be produced artificially, in *A. cajennense* and *A. göldii*, by the forcible removal from the host, before engorgement was complete, of individuals in the larval or nymphal stages. Aragão also observed parallel examples in collections of other species of *Amblyomma* which passed through his hands, notably, *fossum* and *braziliense*. The condition is, therefore, generally attributable to malnutrition.

In some notes on the genus *Rhipicephalus*, Warburton (1912) commented on the frequent occurrence of variation in size of *Rhipicephalus* males, and his paper is illustrated with some striking figures representing pairs of males of three different species, each pair having been derived from a single host.

Nuttall (1913), who for some long time had suspected the true cause of this variability, but was forestalled in publication by Aragão, has since published some remarkable results which he obtained with *Rhipicephalus appendiculatus* raised in his laboratory; and, subsequently, Cunliffe (1913 and 1914), working in Nuttall's laboratory, obtained confirmatory results with *R. pulchellus*, and, experimentally, with *R. sanguineus*.

In the course of work on ticks, chiefly of the genus *Amblyomma*, the author has come across numerous examples of variability of this nature, and as the particular case which forms the subject of this note is an instance which has occurred under more or less natural conditions, as distinct from observations made on laboratory-raised stock, he ventures to believe that the case is sufficiently interesting to be placed on record.

The tick material under consideration is all derived from a South African estate—Gonubie Park—an experimental stock farm, the property of Messrs William Cooper and Nephews, situated on the coast, some ten miles east of East London. At the time that it was acquired by its present owners (1905), the estate was heavily infested with ticks, comprising all the species to be found in that part of Africa. The Bont tick (*Amblyomma hebraeum*) was a common species, and could be obtained in large quantities, and, until April or May, 1906, consignments collected on the estate were sent to this laboratory at frequent intervals.

As a result of the regular practice of dipping the stock running on the estate, the ticks began to disappear, and by the following season it was with the greatest difficulty that we could obtain supplies from this source, which had hitherto proved so fertile. The eradication of the ticks proceeded so rapidly, that in 1908 the greater part of the estate was practically tick-free, and Mr W. F. Cooper, who sent me specimens of *Amblyomma hebraeum* at this time, reported that this species was confined to a ravine which ran through a part of the estate. This ravine had not been cleared, and the rank vegetation afforded excellent cover for many kinds of wild game, especially hares and duiker, and it was upon such hosts that the ticks had mainly subsisted for two seasons.

The correlation diagrams (Figs. 1 and 2) represent measurements of the length and breadth of the scutum in two lots of *Amblyomma hebraeum* males. Lot No. C. 263, comprising 80 individuals, was collected by Dr S. Williamson at Gonubie Park, in 1905. The diagram (Fig. 1) shows that the length of the scutum ranged from 5·7 mm. to 4·2 mm., the breadth from 4·9 mm. to 3·5 mm., while the mean $\frac{\text{breadth}}{\text{length}}$ ratio is

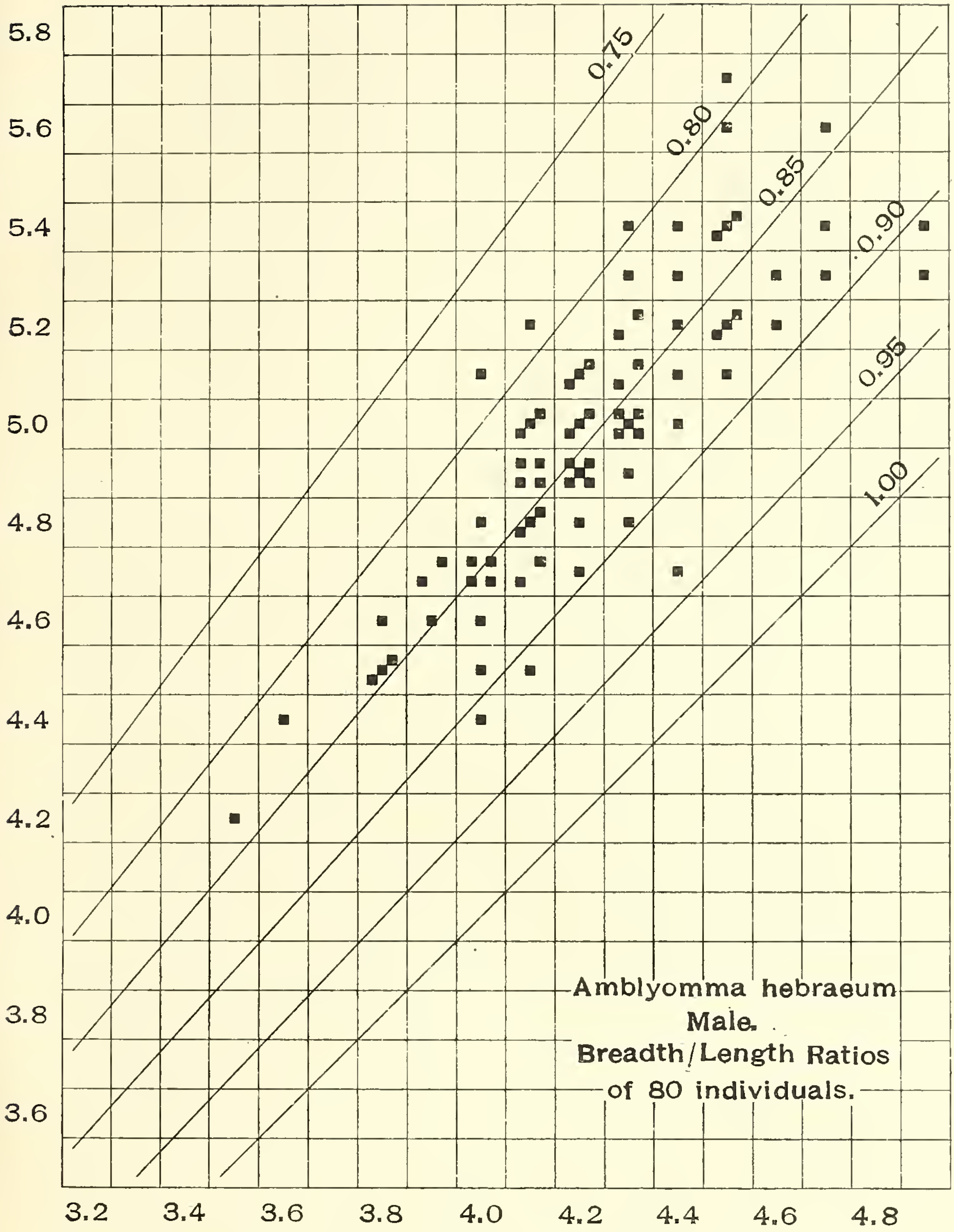


Fig. 1. Correlation diagram of the measurements of length and breadth of 80 males of *Amblyomma hebraeum* (Lot No. C. 263) collected at Gonubie Park, S. Africa, in 1905. Lengths plotted as abscissae, breadths plotted as ordinates; all measurements in millimetres. The inclined lines indicate the principal $\frac{\text{breadth}}{\text{length}}$ ratios.

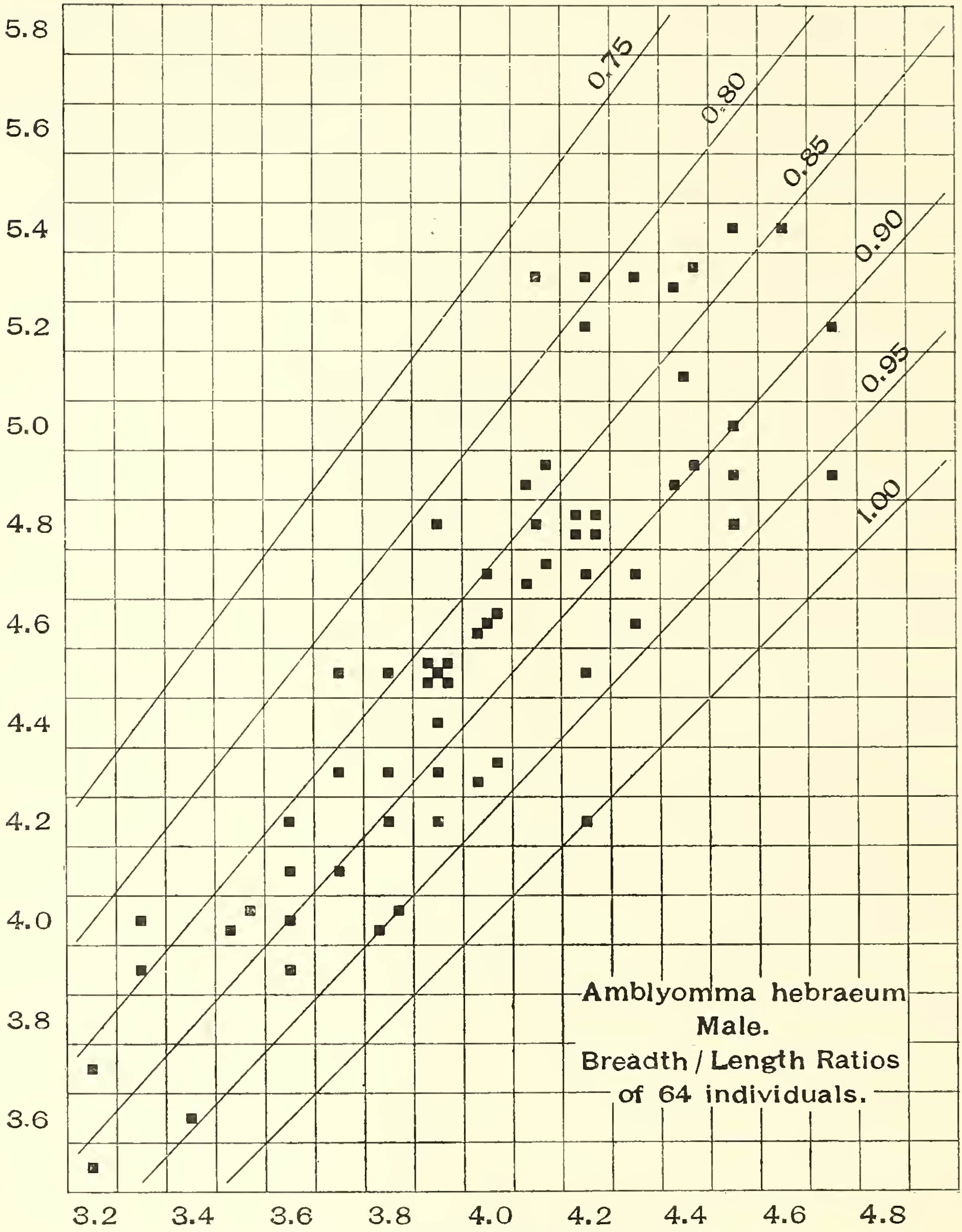


Fig. 2. Correlation diagram of the measurements of length and breadth of 64 males of *Amblyomma hebraeum* (Lot No. C 309) collected at Gonubie Park, S. Africa, in 1908. Other details as in Fig. 1.

0·85 approximately. In the case of Lot No. C. 309, comprising 64 males, collected at Gonubie Park in 1908 by Mr W. F. Cooper, it is seen (Fig. 2) that the length of the scutum ranges between 5·4 mm. and 3·5 mm., the maximum and minimum breadths are 4·7 mm. and 3·2 mm. respectively, while the mean $\frac{\text{breadth}}{\text{length}}$ ratio has risen to 0·87. For purposes of comparison, these figures are set out in tabular form below:

Measurement	Lot No. C. 263 (collected in 1905)	Lot No. C. 309 (collected in 1908)
Maximum length	5·7 mm.	5·4 mm.
Minimum ,,	4·2	3·5
Mean ,,	4·97	4·56
Maximum breadth	4·9	4·7
Minimum ,,	3·5	3·2
Mean ,,	4·22	4·0
Maximum $\frac{\text{breadth}}{\text{length}}$ ratio	0·94	1·00
Minimum ,, ,,	0·78	0·77
Mean ,, ,,	0·85	0·87

A comparison of the two diagrams shows a striking difference in the general disposition of the square dots representing the individual ticks; in Fig. 1 the dots are collected in an elongate but moderately compact group, while in Fig. 2 they are widely scattered; a fact which is, of course, explained by the greater variability in size of the ticks which had lived under the adverse conditions brought about by the measures taken for tick eradication.

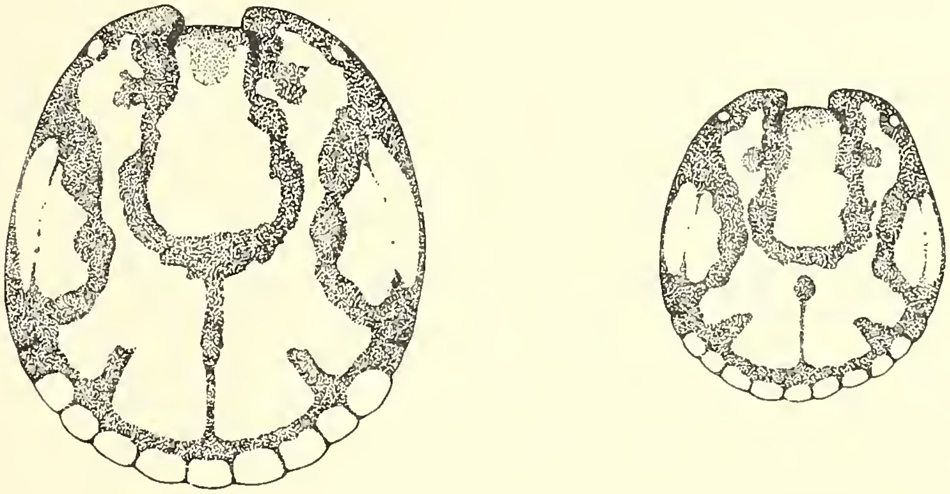


Fig. 3. *Amblyomma hebraeum* ♂. The scuta of the largest and smallest individuals of Lot No. C. 309. Magnified 10 diameters.

Fig. 3 conveys a clearer impression than bare measurements of the remarkable difference in size of the extreme individuals in the series comprising Lot No. C. 309.

REFERENCES.

Aragão, H. de B. (1911). Notas sobre ixódidas brazileiros. *Mem. do Inst. Oswaldo Cruz*, III. 145–146.

—— (1912). Contribuição para a sistematica e biolojia dos ixódidas. *Ibid.*, IV. 114–117.

Cunliffe, N. (1913). The variability of *Rhipicephalus pulchellus* (Gerstäcker, 1873). *Parasitology*, VI. 204–216.

—— (1914). *Rhipicephalus sanguineus*: variation in size and structure due to nutrition. *Ibid.*, VI. 372–378.

Nuttall, G. H. F. (1913). *Rhipicephalus appendiculatus*: variation in size and structure due to nutrition. *Ibid.*, VI. 195–203.

Warburton, C. (1912). Notes on the genus *Rhipicephalus*, with the description of new species, etc. *Ibid.*, V. 3.

IS *LEUCOCYTOZOON ANATIS* THE CAUSE OF A NEW DISEASE IN DUCKS?

By A. B. WICKWARE,

Assistant Pathologist, Health of Animals—Biological Laboratory, Ottawa, Canada.

(With Plates I—III.)

During the past summer numerous inquiries were received by Professor Elford, Dominion Poultry Husbandman, Experimental Farm, Ottawa, with regard to an apparently infectious disease appearing among ducks. So frequent and insistent were the appeals for aid in this connection that the co-operation of the Health of Animals Branch was requested. This resulted in an investigation being undertaken to ascertain the clinical nature of the disease; to demonstrate, if possible, the cause; and also institute measures for its prevention.

As a serious outbreak had occurred on a poultry farm in the vicinity of Ottawa, Ont., which threatened to jeopardize the existence of the plant, this place was chosen as a favourable location for commencing studies.

On arrival at the poultry farm in question, it was learned that the young ducks had been dying on an average of 20 a day. The losses would continue thus for a few days, after which there appeared to be a remission for about a ten day period, with a recurrence at the expiration of this time when the fatalities would again be enormous.

Symptoms of the Disease. The affection runs a rapid and fatal course with very slight prodromal symptoms to indicate its onset. The first clinical feature observed is an impaired appetite. This reluctance to take the ordinary amount of food is particularly noticeable in ducks having access to swimming pools. These birds prefer to remain in the cool water undisturbed, evincing no response to the call for feeding, and this fact is indeed significant.

The attitude of affected individuals varies considerably, depending upon the course of the disease. In some instances, ducks succumb during the first severe paroxysm, while in others exacerbations occur at intermittent periods without producing a fatal result. Affected ducks will lie in a semi-comatose condition with the neck bent backwards and the head resting upon the dorsal portion of the spinal column. When roused this condition of stupor gives way to a period of intense excitement, during which a series of remarkable evolutions are indulged in. The head occupies various positions, sometimes describing circles in the air, and at other periods, oscillating to and fro. In others the neck is completely turned upon itself with the head resting upon the ground in an upright position, as shown in Pl. I, figs. 1 and 2.

The power of equilibrium is also lost, the duck turning over backwards until completely exhausted. In the majority of recovered birds, there also appears to be some difficulty in locomotion, a decided lameness being present in one or other of the legs, usually the left one. Another manifestation which is fairly constant, is a purulent ophthalmia, the eyes being completely closed with the lids adherent to·each other.

The mortality is exceptionally high, probably aggregating to 65–70 %, while the ducks which recover remain undersized and stunted (Pl. I, fig. 3).

Etiology. The causative agent is, as yet, undetermined, owing partly to the limited nature of our investigations. When first observed, the manifest cerebral disturbance was attributed by some poultrymen to the development of insect larvae in the nasal chambers through the deposition of eggs by a species of blue fly. In a few cases larvae were found in the frontal sinuses, but only in those instances in which the affection was running a subacute course, the eggs probably being deposited after the duck was semi-comatose or moribund. In autopsies where the disease ran an acute course, larvae were never found.

Microscopic examinations of the cerebro-spinal fluid, peritoneal exudates, etc., failed to reveal any organisms to which a pathogenic rôle could be ascribed, but as laboratory facilities were lacking at the time, cultural methods could not then be adopted, thus nullifying any general conclusion which might be drawn.

An examination of the blood revealed a *Leucocytozoon* which was present in large numbers in the peripheral circulation of the affected ducks.

Leucocytozoon anatis. This parasite, to which so far as we are aware, no previous reference has been made, was observed during the course of the investigations. Subsequently, identical parasites were demonstrated in the blood of ducks similarly affected on the Experimental Farm, Ottawa. In view of the fact that no record of this parasite can be found, we are naming it "*Leucocytozoon anatis.*"

The parasites were present in large numbers in the peripheral circulation of ducks in which the affection ran an acute and fatal course. Smears from the spleen also showed an abundance of parasites. These protozoa gradually diminished in number in the ducks which made an apparent recovery, while in contact birds which presented no clinical manifestations, parasites were not demonstrable. Examination of the blood of other contact fowls as well as ducks from sources where the disease was not prevalent, failed to reveal any hematozoa.

Morphology. The shape of the parasites is fairly uniform, although there appears to be considerable pleomorphism in the gamete forms. The predominant type is a spindle-shaped organism, 35μ to 60μ in length by 10μ in width, showing an oval, elongated or irregularly shaped nucleus, with a dark chromatic band extending along one border. The nucleus stains, with Giemsa, a dark blue having a granular appearance. In the centre may be observed a small chromatin staining body varying slightly in shape. The cytoplasm appears almost transparent or at most stains a faint pink and terminates at each end in an acute angle. Although, as previously mentioned, there is marked uniformity in shape, it might be advisable to state that considerable variation occurs in the staining characteristics of the mature forms. The chromatic band is similar in all instances, but in certain adult forms the nucleus stains indistinctly a light blue with radiating filaments of chromatin throughout.

Examined in fresh blood preparations, the parasite appears to be non-motile, but as it has recently been shown at Khartoum that motility is present in some of the larger forms, further studies must be undertaken before making a positive statement in this respect.

Pathological Anatomy. Microscopically the visceral organs fail to show any abnormality excepting an acute haemorrhagic inflammation of the large intestine immediately behind the caeca. The normal body fluids appear unaltered, while scrapings from the intestinal wall and examinations of the bowel content show an absence of coccidia or other parasites. In some of the ducks examined, the mouth and pharynx contained a considerable quantity of blood and mucus, the former probably being due to traumatic injuries sustained through the head coming in violent contact with the ground during the paroxysms.

The blood in all cases of infection showed an increase of eosinophiles, and the presence of *Leucocytozoon anatis.*

Transmission Experiments. Our investigations along this line were necessarily limited, as experiments were conducted at the laboratory and all the affected ducks died excepting one survivor which was the only source from which material was available.

Young ducks, three weeks old, were inoculated intraperitoneally with blood taken directly from the affected individual, and placed in a colony house free from infection. Control ducks from the same source were employed. A systematic examination of the peripheral circulation of these experimental ducks for some days previous to inoculation, together with the controls, was conducted. These resulted negatively in every instance, no variation from the normal being observed. Subsequent to inoculation, these examinations were continued daily and on the seventh day two gamete forms were noted in the blood of one of the artificially infected ducks. The controls appeared normal. These earliest forms appeared as organisms showing a transparent cytoplasm containing a few basophilic granules, with a band of chromatin at one side but possessing no nucleus. Three days afterwards, the typical gamete forms appeared showing the dark blue nucleus. These forms persisted for a few days and then suddenly disappeared. No mature forms were present in the smears examined at any time during the period of observation. White rats were also inoculated, but these proved refractory to infection.

Conclusions. No general conclusions can be drawn until further experimental studies are undertaken, but a few salient features may be briefly summarized in closing. That the *Leucocytozoon* above described is the causative agent of this disease, we are not prepared to say. The fact, however, that this parasite was present in large numbers in all affected birds and absent in all the controls coming under our observation, is rather significant. Another peculiar feature is the disappearance of the mature forms from the blood stream of the affected duck in our possession which seemed to coincide with the period of recovery.

The reason of our failure to transmit the disease may possibly be attributable to: (1) The attenuated virulence of the parasite owing to the fact that the disease in this instance was running a chronic course and the duck was progressing towards recovery. (2) The fact that the disease appears to be prevalent only in the hot months of the year, as no fresh outbreaks have occurred at any of the plants under observation. (3) The fact that gamete forms appeared in one of the

FIGURE I

FIGURE II

FIGURE III
Recovered duck on right (five months old) with two controls (two months old)

Various forms of parasites (from slide stained with Giemsa)

Parasites free in blood stream (actual field)

experimental ducks and then disappeared, might be taken to indicate that the disease, in an acute form, is not directly transmissible, the parasite undergoing an exogenous life-cycle dependent for its propagation upon some intermediate host, possibly an insect.

Providing opportunity presents itself, we intend undertaking a more methodical research into the etiology, prophylaxis and treatment of this affection.

I wish to express my indebtedness to Dr F. Torrance, Veterinary Director General, for permission to publish this preliminary report, also for facilities afforded me at the Laboratory and the hearty co-operation of the officials of the Poultry Department.

REFERENCES.

França, C. (1912). Contribution à l'étude des *Leucocytozoon* des Oiseaux du Portugal. *Bull. Soc. Path. Exot.*, v. pp. 17, 82, 173.

Kerandel, J. (1913). Trypanosomata et Leucocytozoa des Oiseaux du Congo. *Annales de l'Institut Pasteur.*

THE TREMATODE PARASITES OF NORTH QUEENSLAND. III.

PARASITES OF FISHES.

By WILLIAM NICOLL, M.A., D.Sc., M.D.
(*Australian Institute of Tropical Medicine, Townsville, Queensland.*)

(With Plates IV and V.)

CONTENTS.

During the past year a considerable number of fishes has been forwarded to the Institute for examination. The great majority have been marine fishes obtained from Cleveland Bay, or from the reefs off Magnetic Island, but a few fresh-water fishes from local creeks have also been included.

From one point of view the result of this investigation is rather disappointing as only a comparatively low percentage (48 %) of fish were found to be infected with worms of any kind, while Trematode parasites were found in only 21 %. This, however, was compensated for by the rich variety and interesting nature of the worms collected. The few which are described in this paper appear to indicate that the parasite fauna of Australian fishes will furnish many forms of extreme interest. This is evidenced by the fact that more than half of the species described here represent new generic types differing considerably from those occurring in other parts of the world.

Genus *Maculifer* n. g.

Maculifer sub-aequiporus n. sp.

(Plate IV, fig. 1.)

This is apparently an extremely common intestinal parasite of the toad-fishes. I have collected, personally, numerous specimens from the intestine of the spotted toad-fish (*Sphaeroides multistriatus*). Amongst the collection in the museum of this Institute there are also specimens from the black and the striped toad-fish (both identified as "*Tetraodon hispidum*"). Possibly these latter collections are from the same host as that from which I have personally taken the parasite.

The most striking feature of this form is its excessively spotted appearance. This is due to the presence of a large number of dark brown pigment patches varying in diameter from the smallest speck up to 0·07 mm. These are not merely sub-cuticular but are scattered throughout the entire substance of the body, being most numerous in the lateral fields. They occur even in the suckers but they do not invade the genital glands. They do not appear to stand in intimate relation to any of the internal organs or systems, but they may possibly be connected with the excretory system, as the granules of which the patches are composed bear some resemblance to those occasionally met with in the excretory tubules of other Trematodes (e.g. *Dasymetra conferta*).

The general body shape is elongated oval with the ends gently rounded. Sometimes a slight constriction is present just behind the ventral sucker. At this point the anterior and posterior halves of the body are usually bent on each other dorsally and the ventral sucker, in consequence, is rendered prominent. There are no cuticular spines.

The length of mature specimens varies from 1·5 to 3·6 mm. and the greatest breadth is about three-sevenths of the length. The smallest immature specimen collected was 0·6 mm. long. Pigment spots were present in as great profusion as in the adults.

The sub-terminal oral sucker measures 0·43 × 0·40 mm. and the ventral sucker 0·46 × 0·54 mm. in a specimen 3 mm. long. The latter is situated a trifle in front of the middle of the body. In young specimens, however, it lies behind the middle.

The well-marked prepharynx is of rather unusual structure. It consists of two parts, an anterior muscular ring attached to the oral sucker and a thin-walled posterior part. The fibres of the muscular part, which are apparently mostly longitudinal, are attached to the outer side of the external limiting membrane of the sucker. At the other end they are attached to the cuticle lining the prepharyngeal cavity. This muscular structure is bounded by an extremely delicate limiting membrane. The posterior part of the prepharynx conforms to the usual type. Its total length is 0·07 mm. The pharynx is extremely well developed and measures 0·27 × 0·29 mm. The wide oesophagus is about a third of the length of the pharynx. The diverticula are uniformly wide and extend to near the posterior end of the body.

The excretory vesicle is a simple narrow tube which reaches the level of the ovary.

The genitalia conform to the type of the ALLOCREADIIDAE. The median genital aperture is situated over the intestinal bifurcation and the short plump cirrus-pouch extends back to the anterior border of the ventral sucker. The walls of the pouch are very thin and poorly supplied with muscle fibres. Inside the pouch there is a large highly convoluted vesicula seminalis and a simple straight ductus. A moderate number of prostatic cells are present within the pouch but there is no distinctly differentiated pars prostatica. The testes lie in the posterior third of the body directly behind and contiguous with each other. The post-testicular space is a little less than one-sixth of the body length. The testes are transverse, roughly oval, bodies, their greatest diameter being about one-quarter of the maximum breadth of the body.

Immediately in front of the anterior testis and contiguous with it lies the ovary which is transversely oval in outline and has a greatest diameter of about three-quarters that of the testes. It is displaced somewhat to the right side. On its anterior border and still further to the right lies a globular receptaculum seminis. A short Laurer's canal is present. The yolk glands are fairly voluminous but are somewhat obscured by the pigment spots. They are mainly lateral and extend from the pharynx to the posterior end of the body where they fill up the post-testicular space. They overlap the intestinal diverticula and are found in considerable numbers on the inner side of the latter. The uterus is of restricted extent and the ova are not numerous. They measure about 0·060–0·063 × 0·034–0·039 mm. They are provided with a small knob at the anopercular pole.

This species presents an undoubted affinity with the ALLOCREADIIDAE but the structure of the prepharynx and the presence of pigment spots mark it out as a distinct type.

Genus *Coitocoecum* n. g.

Coitocoecum gymnophallum n. sp.

(Plate IV, fig. 2.)

About half a dozen specimens of another somewhat remarkable parasite were obtained from the intestine of a black bream (*Sparus australis*). It is a small, plump, elongated oval species with rather pointed ends, and it has a distinct lemon-yellow colour.

Although they may reach a length of 3 mm., most of the specimens are considerably smaller. The following measurements are taken from the largest specimen. The breadth, which is fairly uniform, reaches a maximum of a little more than one-third of the length. There are no cuticular spines.

The sub-terminal oral sucker is somewhat transverse and measures 0·27 × 0·31 mm. The ventral sucker is decidedly transverse and measures 0·43 × 0·57 mm. It is situated three-eighths of the body length from the anterior end.

There is a well-marked prepharynx, 0·1 mm. in length, a fairly large pharynx, 0·21 mm. in diameter, and a short oesophagus about 0·06 mm. long. The diverticula are of medium width and fairly uniform. They extend along the sides of the body to near the posterior end, *where they unite* in a rounded arch. This condition resembles that in the Cyclocoelid Monostomes but is extremely rare amongst the Distomata. It is the more remarkable in consideration of the fact that the species in other respects is closely allied to the ALLOCREADIIDAE. It presents an analogous case to that of *Genarches* and *Derogenes*.

The excretory vesicle is a short straight tube terminating just behind the ovary.

The genital aperture is situated near the left side of the middle of the pharynx. There is no true cirrus-pouch. The large simple vesicula seminalis lies immediately in front of the ventral sucker. There are a few prostatic cells but no definite pars prostatica. The ductus is moderately long. The testes lie in the posterior third of the body, the post-testicular space being a little more than one-fifth of the body length. They are tandem and contiguous. In outline they are roughly oval with a slight concavity on their anterior border. The margins are irregularly crenated. They measure about 0·28 × 0·46 mm.

The ovary lies on the right immediately in front of the anterior testis, with which it is contiguous. It is a small oval body measuring 0·12 × 0·19 mm. There is no receptaculum seminis but Laurer's canal is present. The yolk glands are chiefly lateral and extend from the level of the ventral sucker to the posterior end of the body where they fill the post-testicular space. They extend inwards over the intestinal diverticula and overlap the testes to some extent. The uterus lies between the ovary and the ventral sucker. The ova, which are few in number, measure 0·081–0·084 × 0·042–0·043 mm.

It is difficult to place this species in the system. It bears a superficial resemblance to the ALLOCREADIIDAE but the absence of a cirrus-pouch and the condition of the intestinal diverticula appear to exclude it from that family.

Genus *Aephnidiogenes* n. g.

Aephnidiogenes barbarus n. sp.

(Plate IV, fig. 3.)

About a dozen specimens of this parasite were obtained from the intestine of a large grunter (*Pomadasis hasta*). It is an elongated flat species of almost uniform width and with rounded ends. In several specimens a slight constriction was noticed at the level of the oesophagus, but this does not appear to be a constant feature. The thick cuticle in the anterior two-thirds of the body is covered with minute spines.

The length of mature specimens is 4–5·5 mm. Specimens under 4 mm. in length contain no ova, or only malformed ones. The maximum breadth which occurs at the level of the testes is 0·75–1·0 mm. The margins of the body are very lightly wrinkled.

The oral sucker is usually sub-terminal, though in contracted specimens it may be terminal. Its diameter measures 0·27–0·31 mm. The ventral sucker, which is situated one-fifth of the body length from the anterior end, is transversely oval and measures 0·19 × 0·21 mm. The sucker ratio is, therefore, rather less than 3 : 2.

The pharynx is contiguous with the oral sucker and has a somewhat square outline. Its length and breadth are both about 0·12 mm. The oesophagus is short, rarely exceeding the pharynx in length. Its average length is about 0·075 mm. The intestinal bifurcation forms rather an acute angle and the diverticula maintain a position at some distance from the edges of the body throughout their whole extent. They reach to within a short distance of the posterior end of the body. They are of moderate width and somewhat irregular contour.

The median genital aperture lies rather less than 0·1 mm. in front of the ventral sucker. The terminal male genitalia are of unusual type. The cirrus-pouch is reduced to enclose only the terminal part of the ductus and forms an oval muscular genital sinus, into the side of which the uterus opens. The sinus measures 0·13 × 0·10 mm. and lies entirely in front of the ventral sucker, with which it is almost contiguous. Into the proximal end of the sinus opens the short ductus, which issues from a large pars prostatica. The latter curves round the left border of the ventral sucker and is surrounded by large masses of prostatic cells, which lie free in the body parenchyma. The vesicula seminalis, which also lies free, is comparatively large and extremely convoluted. It is situated in the space between the ventral sucker and the ovary.

The ovary lies on the right side about 0·26 mm. behind the ventral sucker. It is an irregularly ovoid body and its outline shows one or two indentations. Its dimensions are 0·26 × 0·21 mm. The testes are obliquely tandem. The anterior testis lies 0·25 mm. behind the ovary, on the left side and close against the left intestinal diverticulum. The posterior testis is separated from it by a space of 0·16 mm. and lies close against the right intestinal diverticulum. Both are ovoid or subglobular and their outline is distinctly crenated. The mean diameter of the testes is about 0·46 mm. but the posterior is, as a rule, a trifle larger and more ovoid. The post-testicular space is rather more than two-fifths of the body length.

Alongside the ovary is a small discrete shell gland. The yolk glands are very voluminous. They are lateral and extend from the level of the ovary to near the posterior end of the body. They completely enclose the intestinal diverticula but do not overlap the ovary or testes. In the post-testicular space they attain a width of 0·4 mm. on each side and leave only a small clear space in the middle line of the body. Occasionally there appears to be a tendency to fusion towards the end of the body, but as a rule the glands on each side are distinctly separated throughout their whole extent.

The uterus is poorly developed and is confined to the space between the anterior testis and the ventral sucker. In no case were eggs observed behind the anterior border of the anterior testis. The eggs are few in number and thin-shelled, with a well-marked operculum at the blunt pole. They measure 0·061–0·064 × 0·039–0·041 mm.

This species bears a certain resemblance to *Distomum levenseni* described by Linton (1907) from Bermuda fishes (*Epinephelus maculosus* and *E. striatus*). From Linton's descriptions and figures (Figs. 80 and 81), however, it is almost certain that under the name *D. levenseni* he has included two entirely distinct species differing markedly from each other in the extent of the yolk glands and in the size of the ova. In the one the yolk glands extend more than half the length of the body and the eggs measure 0·065 × 0·04 mm. In the other the yolk glands are confined to a small area at the level of the ovary and the eggs measure only 0·046 × 0·023 mm.

In regard to the relation between these American species and *Aephnidiogenes barbarus* it is evident that all three display a close resemblance in body form and in the size and position of the suckers. The alimentary system is also very similar, the diverticula in all three displaying the tendency to avoid the margin of the body and keep closer to the mid line. On the other hand in the American species the genital glands are situated much nearer the posterior end and the testes are distinctly tandem. The position of the uterus, again, is not quite identical.

By the kindness of Professor Linton several specimens of *Distomum levenseni* were forwarded to me for examination. They all belong to the type with extensive yolk glands and large eggs. From this material I was able to confirm the details of Linton's description and also to determine that the structure of the terminal male genitalia agreed in all essentials with that in *Aephnidiogenes barbarus*. There can, therefore, be little hesitation in including *Distomum levenseni* in the genus *Aephnidiogenes*.

The difficulty still remains of determining which of the American forms is to be regarded as *Distomum levenseni*. In his general description Linton specifically mentions that the yolk glands extend throughout the greater part of the body behind the ventral sucker, but no mention is made of the size of the ova. This appears to be sufficient ground for regarding the form with extensive yolk glands as the true *D. levenseni*, especially as this was the form submitted to me as such. The fact that the form with abbreviated yolk glands appears first in the list of illustrations does not seem of much weight. I regard this form as a distinct species and for it I propose the name *Aephnidiogenes ptochus* n. sp.

The diagnosis of the two forms may be summed up as follows:

Aephnidiogenes levenseni (Linton).

Length 0·95–3·45 mm.; breadth 0·4–0·6 mm., cuticle covered with spines quite to posterior end. Oral sucker 0·09–0·13 mm.; ventral sucker 0·09–0·16 mm., situated a quarter of the body length from the anterior end. Pharynx 0·05–0·10 mm. in diameter. Intestine as in *A. barbarus.* Ovary and testes in the posterior half of the body almost directly tandem. Post-testicular space only one-sixth of the body length. Yolk glands extending from the posterior end of the body to midway between the ovary and ventral sucker. Uterus between ovary and ventral sucker. Ova 0·06–0·07 × 0·04 mm.

Aephnidiogenes ptochus n. sp.

Length 1·3–2·8 mm.; breadth 0·33–0·68 mm. Suckers each 0·08–0·24 mm. Yolk glands confined to the region of the ovary and only extending along the sides about one-fifth of the length of the body. Ova 0·045–0·048 × 0·022–0·024 mm. Otherwise similar to *A. levenseni.*

The diagnosis of the genus *Aephnidiogenes* may be briefly summarised thus:

Flat, elongated distomes of moderate size with spiny cuticle. Suckers small and not far distant from each other. Prepharynx absent, oesophagus short, diverticula long. Testes tandem or slightly oblique, in posterior half of the body; ovary in front of the testes. Yolk glands lateral, either restricted to region of ovary or extending along considerable part of body. Uterus short, not extending back beyond anterior testis. Ova measure 0·045–0·07 × 0·022–0·04 mm. Terminal male genitalia consist of muscular genital sinus into which the terminal part of the uterus opens, a small pars prostatica and large convoluted vesicula seminalis, neither of which is enclosed in a cirrus-pouch.

Habitat: intestine of Marine Fishes, Queensland and Bermuda.

Type: *A. barbarus* from *Pomadasis hasta.*

Genus *Genolopa* Linton

Genolopa trifolifer n. sp.

(Plate IV, fig. 4.)

Several specimens of this interesting parasite were obtained from the intestine and coeca of a grunter (*Pomadasis hasta*). A single specimen also occurred in the swim-bladder. It is a small species measuring 1·5–2·1 mm. in length. The general outline is oval with pointed ends. The greatest breadth, which occurs a little behind the middle of the body, is 0·3–0·7 mm. Not infrequently the body is of fairly uniform breadth throughout with the anterior end somewhat pointed. The cuticle is thickly beset with stout spines, which cover the whole body to within a short distance of the tail.

The oral sucker is almost terminal and measures 0·18 mm. In one specimen it was found retracted within the body almost to the level of the ventral sucker. The inconspicuous ventral sucker is situated a third of the body length from the anterior end and measures 0·10 × 0·13 mm., being somewhat transversely oval.

The prepharynx is almost absent. The small globular pharynx has a diameter of 0·07 mm.; the oesophagus is slightly longer (0·1 mm.). The intestinal diverticula are narrow and extend to within a short distance of the tip of the tail. The genital aperture is median and a little in front of the ventral sucker. The comparatively large cirrus-pouch bends round the right border of the ventral sucker and extends about 0·1 mm. behind it. Its total length is over 0·4 mm. and its greatest width about 0·15 mm. It contains a small ovoid vesicula seminalis, a long pars prostatica and a short wide cirrus. No spines could be detected on the cirrus, but from analogy with other species of this group it is probable they are present.

There is a large vaginal sac, with thick walls, extending from the genital aperture, on the left side of the ventral sucker. It measures 0·25 × 0·13 mm. The uterus opens into this sac laterally on its inner side and somewhat in front of its middle. This arrangement resembles that in *Monorchis monorchis* but in that species the uterus opens into the sac behind its mid point. No spines could be seen in any part of the sac.

Alongside the outer border of the posterior part of the cirrus-pouch lies the ovary, which is decidedly trilobate in outline. Its greatest length is 0·25 mm.

Immediately behind the ovary, but lying almost in the middle of the body, is the large single testis. It is broadly ovo-cordate in outline and measures 0·38 × 0·36 mm. It is not overlapped by the uterus. The post-testicular space measures 0·8 mm.

Laterally on the level of the ovary lie the yolk glands, each of which consists of 8–10 large follicles, bunched together. The yolk gland on the right side overlaps the outer margin of the ovary to a considerable extent. The diameter of the follicles is about 0·07 mm. From each yolk gland issues a conspicuous duct which runs along the anterior border of the testis. There is no receptaculum seminis.

The uterus is very voluminous and fills the whole of the post-testicular space. It is highly convoluted, the convolutions being mostly transverse and densely packed together. The terminal part of the uterus runs up on the left side of the testis to enter the vaginal sac. The ova are thin-shelled and of small size, measuring only 0·018–0·026 × 0·012–0·013 mm. The size of the eggs is fairly constant in each specimen, but varies considerably in different specimens. In some they are more sharply pointed than in others.

This species is obviously a member of the family MONORCHIIDAE and it appears to be most closely related to the genus *Genolopa* Linton (1910), and to the type species *G. ampullacea* Linton. The latter is a much smaller form but the one outstanding difference in the internal anatomy lies in the shape of the ovary, which in *G. ampullacea* is roughly triangular. In the latter species, moreover, a receptaculum seminis is stated to be present, while well-marked spines occur on the cirrus, though not in the vaginal sac.

Genolopa cacuminata n. sp.

(Plate IV, fig. 5.)

Along with *Genolopa trifolifer* numerous specimens of a distinct, though allied, species occurred in the intestine of the grunter (*Pomadasis hasta*). A single specimen also occurred in the swim bladder. They are readily picked out by reason of their more slender shape.

It is an elongated form measuring 2·1–3·25 mm. in length with a maximum breadth of 0·5–0·64 mm. The widest part is just behind the middle of the body. From there it tapers rapidly towards the sharply pointed tail and more gradually towards the anterior end. The neck is long drawn out and slender. The anterior part of the body is clothed with thickly set spines, but these are apparently absent behind the level of the ovary. The following description is from the largest specimen.

The funnel-shaped oral sucker is almost terminal and measures 0·15 × 0·13 mm. The weak ventral sucker is decidedly larger, having a diameter of 0·18 mm. It is situated exactly one-third of the body length from the anterior end.

There is a long, narrow prepharynx 0·19 mm. in length. The pharynx is sub-globular and measures 0·12 × 0·11 mm. It is succeeded by a slender oesophagus about the same length as the prepharynx. The intestinal diverticula are narrow and terminate some distance from the posterior end of the body.

The genital aperture is situated immediately in front of the ventral sucker. The cirrus-pouch is elongated and club-shaped. Its dimensions are 0·7 × 0·25 mm. and it extends a trifle beyond the middle of the body.

It contains a large vesicula seminalis, a long pars prostatica and a short cirrus which is thickly set with short straight delicate spines totally different from those on the external surface of the body.

The vaginal sac is also elongated, being about two-thirds of the length of the cirrus-pouch. It is divided into a proximal and a distal part at the point where the uterus enters it, namely about one-third of its length from the posterior end. It is thick-walled but no trace of spines could be observed in it.

The ovary lies near the posterior end of the cirrus-pouch on its right side and extends some distance beyond the pouch. It is oval with its long axis oblique and measures 0·29 × 0·21 mm. Immediately behind it lies the single sub-globular testis, which measures 0·41 × 0·35 mm. It is approximately median in position. The post-testicular space measures exactly 1 mm.

Along the margins of the body in the region of the ovary and testes lie the yolk glands, which are arranged in an irregular row from the level of the anterior border of the ovary to the posterior border of the testis. There are about eight moderately large follicles on each side.

There is no receptaculum seminis. The uterus fills the greater part of the post-testicular space and overlaps the posterior and left borders of the testis to a considerable extent. It passes up along the left border of the ovary and cirrus-pouch to enter the vaginal sac on its inner side. The numerous ova are thin-shelled and measure 0·022 × 0·011–0·012 mm.

It is with some hesitation that this species is included in the genus *Genolopa*, for although it is closely related to it yet there are a few important features of divergence. In the first place the body shape is entirely different. The presence of an elongated prepharynx, which is usually absent in the MONORCHIIDAE, is also of some importance. The inverted ratio of the suckers may also be noted, while the configuration and position of the yolk glands are different. The relative position of the yolk glands, however, with regard to the ovary remains practically the same.

Genus *Sterrhurus* Looss.

Sterrhurus brevicirrus n. sp.

(Plate IV, fig. 6.)

A single specimen of this parasite was taken from the intestine of a grunter (*Pomadasis hasta*). It displays all the typical features of the genus *Sterrhurus* and it is difficult to differentiate it from the already known European forms.

The specimen, which was slightly pressed, measures 2·18 mm. in length with a maximum breadth of 0·73 mm. in the posterior part of the body. The body narrows rapidly in front of the ventral sucker so that the head appears pointed. The ecsoma (appendix) is retracted and does not appear to exceed 0·6 mm. in length.

The oral sucker has a diameter of 0·16 mm. and it has no anterior lappet. The larger globular ventral sucker measures 0·43 mm. and lies 0·64 mm. from the anterior end.

The globular pharynx measures 0·075 mm. and there is neither prepharynx nor oesophagus. The diverticula are wide and reach the posterior end of the soma.

The testes lie immediately behind the ventral sucker, almost symmetrically, the left testis being a little in advance. They are widely separated and their maximum diameter is 0·11 mm.

The ovary is situated 0·4 mm. behind the ventral sucker. It is transversely oval, measuring 0·15 × 0·28 mm. Immediately behind it lie the small yolk glands, with short stumpy digitations, four on the left and three on the right.

The vesicula seminalis extends from the anterior border of the ventral sucker to the intestinal bifurcation. The pars prostatica is short and the prostatic cells few. There is, however, a large prostatic bulb. The short "cirrus-pouch" lies over the pharynx.

The uterus fills the post-acetabular region and there is a long straight metraterm. The numerous ova measure 0·020–0·021 × 0·012 mm.

Genus *Ectenurus* Looss.

Ectenurus angusticauda n. sp.

(Plate IV, fig. 7.)

A single specimen of this parasite was taken from the stomach of an eel (*Muraenesox cinereus*). It is of medium size, the body being 3·1 mm. long and the appendix (ecsoma) extended a distance of 1·15 mm. The latter is characterised by its slenderness.

The body, which is almost cylindrical, is broadest in its posterior half, attaining a maximum breadth of 0·9 mm. Forward it tapers gradually to the anterior end. The cuticle is not markedly annulated, there being only traces of transverse wrinkles present.

The oral sucker has a diameter of 0·22 mm. and the ventral 0·44 mm. The latter is situated 0·88 mm. from the anterior end.

The testes lie adjacent to the posterior border of the ventral sucker and very nearly on the same level. The right testis is transversely oval and measures 0·09 × 0·15 mm. The left testis is apparently abnormal, as it is very much compressed and considerably smaller than the right testis.

The ovary lies 0·1 mm. behind the ventral sucker. It is nearly median and has an irregularly rounded outline. It measures 0·15 × 0·18 mm. On each side and behind it lie the yolk glands which form processes of moderate length. They are fairly straight and markedly transverse in direction. There are three processes on the right and four on the left.

The uterus is poorly developed. It forms only a few windings in the middle of the body and does not enter the appendix. The eggs are remarkably broad, measuring 0·028–0·030 × 0·022–0·023 mm.

The terminal male genitalia do not quite resemble those in *Ectenurus lepidus*, the type of the genus. The pars prostatica is relatively longer, the vesicula seminalis more slender, while the duct connecting the vesicula with the prostate is shorter. The resemblance, however, appears to be sufficiently close to permit of the inclusion of this species in the genus *Ectenurus*. The genital aperture lies over the pharynx. The cirrus-pouch is about 0·15 mm. in length and cylindrical in shape. The pars prostatica is 0·25 mm. in length and the prostatic cells are very closely apposed to it. The long, narrow vesicula is bent to form a right angle. No division into three parts could be detected. The posterior end of the vesicula does not quite reach the posterior border of the ventral sucker.

The species differ from *E. lepidus* chiefly in the structure of the terminal male genitalia and in the size of the ova.

Genus *Xenopera* n. g.

Xenopera insolita n. sp.

(Plate IV, fig. 8.)

Five specimens of a rather peculiar parasite were collected from the rectum of a bream (*Sparus australis*).

It is an elongated, sub-cylindrical form with a pedunculated ventral sucker. The length of the body is 2–2·5 mm. and the maximum breadth, which occurs near the posterior end, is 0·6 mm. The breadth of the neck is only 0·2 mm. There is no appendix or ecsoma and the cuticle is unarmed.

The oral sucker is sub-terminal and measures 0·29 mm. in length by 0·22 mm. in breadth. The ventral sucker measures 0·28 × 0·39 mm., but the transverse diameter is variable. The sucker is raised on a short pedicle and is situated about 0·7 mm. from the anterior end.

The comparatively large pharynx is contiguous with the oral sucker and measures 0·21 × 0·14 mm. There is a short oesophagus about 0·07 mm. long. The intestinal diverticula diverge widely and extend to the posterior end of the body. Near the bifurcation each is somewhat inflated, forming a sight protuberance directed anteriorly.

The genital aperture is situated in the middle line just in front of the ventral sucker, at the base of the pedicle. There is a long tube-like genital sinus which extends straight back to a short distance behind the ventral sucker. Its walls are provided with longitudinal and circular muscle fibres. The cirrus-pouch proper is also elongated and extends back a distance of over 0·5 mm. behind the ventral sucker. It thus extends well beyond the middle of the body. It contains a short ductus ejaculatorius, a long straight pars prostatica, surrounded by numerous prostatic cells, and part of a highly convoluted vesicula seminalis. The greater part of the vesicula, however, lies external to the pouch, and extends some distance behind it, overlapping the ovary.

Immediately behind and adjacent to the end of the cirrus-pouch lies the large globular ovary with a diameter of 0·18 mm. It lies a little to the left side of the middle line. The testes lie just behind the ovary. They are obliquely disposed, the anterior being on the right side. They are closely apposed to each other and have an irregularly ovoid shape. They are somewhat smaller than the ovary, their greatest diameter being only 0·14 mm.

The yolk glands are very poorly developed and are confined to the sides of the body on the level of the ovary and testes, beyond which they do not extend. The yolk follicles are comparatively small and not numerous. There is no receptaculum seminis and the presence of Laurer's canal could not be determined.

The uterus is confined to the posterior part of the body behind the testes. It forms loose straggling convolutions, chiefly in a transverse direction. The terminal part of the uterus unites with the genital sinus at its junction with the cirrus-pouch. The eggs are disposed in a single row and are light in colour. They measure 0·042 × 0·021–0·023 mm.

The systematic position of this species is very doubtful. It betrays unmistakable affinities with the HEMIURIDAE but it shows so many anomalies that it cannot be considered by any means a typical member of the family. The presence of the long tube-like genital sinus is a peculiarly Hemiurid characteristic, but the structure of the remainder of the male end-apparatus is decidedly unusual. Hitherto the only Hemiurid in which the pars prostatica has been found enclosed in a cirrus-pouch is *Hemipera ovocaudata* Nicoll, 1913. In that species the vesicula seminalis is entirely outside the pouch. The relative position of the ovary and testes is the reverse of that usually met with in the family, though it occurs in *Liocerea* Looss, 1902, and *Hemipera.* Finally the arrangement of the yolk glands is quite foreign to the family.

Genus *Opistholebes* n. g.

Opistholebes amplicoelus n. sp.

(Plate V, fig. 9.)

Two specimens of this interesting parasite were taken from the intestine of a green toad-fish (*Sphaeroides lunaris*). Both specimens were slightly pressed before being examined, so that the following measurements are somewhat greater than in a normal specimen.

The outline is oval but the anterior end is more pointed than the posterior end. The latter is rounded but has a distinctly projecting tip. There are no cuticular spines.

The length of the larger specimen is 2 mm. and the maximum breadth is 1·3 mm. The oral sucker, which is globular and sub-terminal, has a diameter of 0·28 mm. The ventral sucker is situated subterminally at the extreme posterior end of the body and measures 0·34 mm. in diameter.

There is a short, wide prepharynx, 0·04 mm. in length, the comparatively large pharynx measuring 0·17 × 0·22 mm. There is no oesophagus; the intestinal diverticula diverge immediately from the pharynx. The diverticula are exceptionally wide, each occupying at least a quarter of the breadth of the body. They extend to the posterior end of the body, their termination being on the level of the aperture of the ventral sucker.

The genital aperture is situated 0·24 mm. behind the pharynx, and is displaced somewhat to the left. The cirrus-pouch is long and slender, stretching obliquely across the body. Its dimensions are 0·45 × 0·125 mm. It consists of an inflated proximal part and a very attenuated distal part. The inflated portion contains the highly convoluted vesicula seminalis, while the attenuated portion is traversed by the ductus ejaculatorius. The pars prostatica is indistinct. The wall of the cirrus-pouch is extremely thin.

The testes are situated immediately in front of the ventral sucker, with which they are contiguous. They lie symmetrically alongside each other, their inner surfaces being in contact. Their shape is somewhat peculiar, their posterior borders being hollowed out to fit the convexity of the ventral sucker. Their outer surfaces are pressed against the intestinal diverticula, while their anterior borders are convex. Their dimensions are 0·18 × 0·23 mm.

Immediately in front of the right testis and contiguous with it lies the large ovary. It is roughly oval in outline and measures 0·16 × 0·22 mm. Its posterior border is pressed close against the right testis. In front of the ovary and alongside the end of the cirrus-pouch lies a large globular receptaculum seminis with a diameter of 0·12 mm. The yolk glands are lateral and extend from the level of the pharynx to the middle of the ventral sucker. They surround the intestinal diverticula, but the majority of the follicles are dorsal. The yolk ducts run down the inner side of the diverticula. The uterus occupies the median field at the left side of the ovary and cirrus-pouch. The ova are not numerous and they measure 0·065–0·07 × 0·03 mm. The vagina is more than half the length of the cirrus-pouch and it has a curiously twisted course.

This species is rather an anomaly as a Distome. At first sight it appears to be an Amphistome, judging from the position of the ventral sucker. The internal anatomy, however, obviously shows that it belongs to the former and not the latter class. Its systematic position among the Distomata must be left for the future to decide.

Genus *Gyliauchen* n. g.

Gyliauchen tarachodes n. sp.

(Plate V, fig. 10.)

A considerable number of specimens of this remarkable parasite were obtained from the intestine of a pilot fish (*Tachysurus* n. sp.). It is a small, elongated, moderately plump form, measuring 2·6–3·5 mm. in length. It is somewhat pointed at both ends, more so at the anterior than at the posterior end. The greatest breadth is about one-third of the length and occurs just behind the middle of the body. There are no cuticular spines and the cuticle is smooth.

The globular oral sucker is sub-terminal and has a diameter of 0·24–0·26 mm. The ventral sucker is almost at the posterior end of the body. It is somewhat elongated and measures on an average 0·50 × 0·47 mm. Both suckers are simple structures of the ordinary distomate type.

The alimentary system is the most interesting feature of this parasite. From the mouth there proceeds backwards an extraordinarily long prepharynx. At first it lies towards the right side of the body, but when it has traversed about one-third of the body length it bends at right angles and passes across to the left side, where it again bends at right angles and passes forward along the left side. Midway on its course towards the anterior end of the body it turns abruptly backwards and passes down the mid line of the body to join the large pharyngeal bulb which is situated over the transverse part of the prepharynx. This configuration is fairly constant and is present in all the specimens. The pharyngeal bulb is extremely muscular and measures 0·28–0·35 × 0·23–0·27 mm. The intestinal diverticula arise directly from the pharynx. They are short, widely dilated and somewhat in the form of a horseshoe. They terminate about two-fifths of the body length from the posterior end.

The genital aperture is median and lies just behind the intestinal bifurcation. There is a stout, muscular cirrus-pouch, ovoid in shape, and measuring about 0·35 × 0·25 mm. It does not enclose the vesicula seminalis. The pars prostatica is of moderate size and almost globular. The ductus is rather wide. The vesicula seminalis, which opens into the pars prostatica without the intervention of any connecting duct, is of large size, being considerably larger than the cirrus-pouch. It is L-shaped, the lower limb being diverted outwards towards the right.

The testes lie a little in front of the ventral sucker. They are not infrequently symmetrical, but are usually slightly oblique. They are placed together and usually overlap a little. They are almost globular with an average diameter of 0·3 mm.

Immediately in front of the testes and a little to the left lies a large globular receptaculum seminis, which is about the same size as the testes. In front of the receptaculum but more towards the mid line lies a smaller oval ovary. It is usually almost contiguous with the vesicula seminalis. The yolk glands are rather scattered and irregular; they are situated for the most part laterally over the intestinal diverticula. They do not extend beyond the latter posteriorly, but anteriorly they extend a little in front of the pharynx. The follicles are small. A very characteristic feature of the species is the course pursued by the yolk ducts. They run down from the posterior end of the yolk glands on each side and pass round the outer edges of the testes. They then run forward and unite between the testes.

The uterus contains very few ova, which lie mostly over and in front of the ovary. They are light yellow in colour and measure 0·078–0·084 × 0·045–0·049 mm.

This parasite presents many interesting peculiarities. It appears undoubtedly to belong to the Amphistomata and to the family PARAMPHISTOMIDAE, but it is difficult to include it in any of the subdivisions of that family. It can certainly not be included in the Paramphistominae owing to the presence of a cirrus-pouch. It bears more general resemblance to some of the members of the Cladorchiinae, but the absence of oral evaginations (pharyngeal pouches), which are apparently constantly present in members of this sub-family, renders it at once an aberrant form. It is probably most closely related to the genus *Pseudocladorchis* Daday from South American fishes, but the relation is a decidedly remote one.

Genus *Bucephalopsis* Diesing.

Bucephalopsis exilis n. sp.

(Plate V, fig. 11.)

Four rather macerated specimens of this parasite were obtained from the intestine of *Caranx nobilis,* and they appear to be distinctly different from any of the already described Gasterostomes from Europe and America. The species bears a certain resemblance to *Bucephalopsis arcuatus* Linton (1905) from *Scomberomorus regalis.*

It is a greatly elongated form, measuring 1·9–2·6 mm. in length. The maximum breadth is only about one-twelfth of the length. The cuticle is covered, throughout the greater part of its extent, by minute spines which become rather sparse towards the posterior end of the body.

The anterior end is furnished with a well-formed sucker, 0·05 mm. in diameter. The pharynx (ventral sucker) is a small inconspicuous structure, difficult to detect. It lies a third of the body length from the posterior end and measures 0·04 mm. in diameter. The intestinal sac is obscured by the uterus.

Alongside the pharynx lies the ovary. It is an oval body measuring 0·1 × 0·07 mm. and its long diameter may be either longitudinal or transverse. The anterior testis lies immediately behind, and contiguous with, the ovary, which it resembles in shape and size. The posterior testis is situated a short distance behind the first and a little nearer the mid line. The slender cirrus-pouch, which lies at the posterior end of the body, is about one-fifth of the body length.

The yolk glands lie along the sides of the body immediately in front of the ovary. They consist of a single row of a dozen follicles on each side. The diameter of the follicles is about 0·03 mm. The most anteriorly situated follicle lies about 1·0 mm. from the anterior end, and the length of the row of follicles is about 0·45 mm. There is a slight degree of asymmetry, the row of follicles on the right side being somewhat in advance of that on the left. The uterus is fairly voluminous and extends forwards to a point about 0·46 mm. from the anterior end of the body. It consists of a single ascending and descending loop. The latter does not cover the testes or ovary. The eggs are of fairly constant size, measuring 0·021 × 0·013 mm.

REFERENCES.

Linton, E. (1905). Parasites of Fishes of Beaufort, North Carolina. *Bull. Bur. Fisheries U.S.A.* xxiv. 321–428.

—— (1907). Notes on Parasites of Bermuda Fishes. *Proc. U.S.A. Nat. Mus.* xxxiii. 85–126.

—— (1910). Helminth Fauna of the Dry Tortugas II. Trematodes. Publication No. 133 of the *Carnegie Institution of Washington*, pp. 11–98.

Looss, A. (1902). Ueber neue und bekannte Trematoden aus Seeschildkröten. *Zoologische Jahrbücher*, Abt. f. System, xvi. 441–894.

Nicoll, W. (1913). New Trematode Parasites from Fishes of the English Channel. *Parasitology*, v. 238–246.

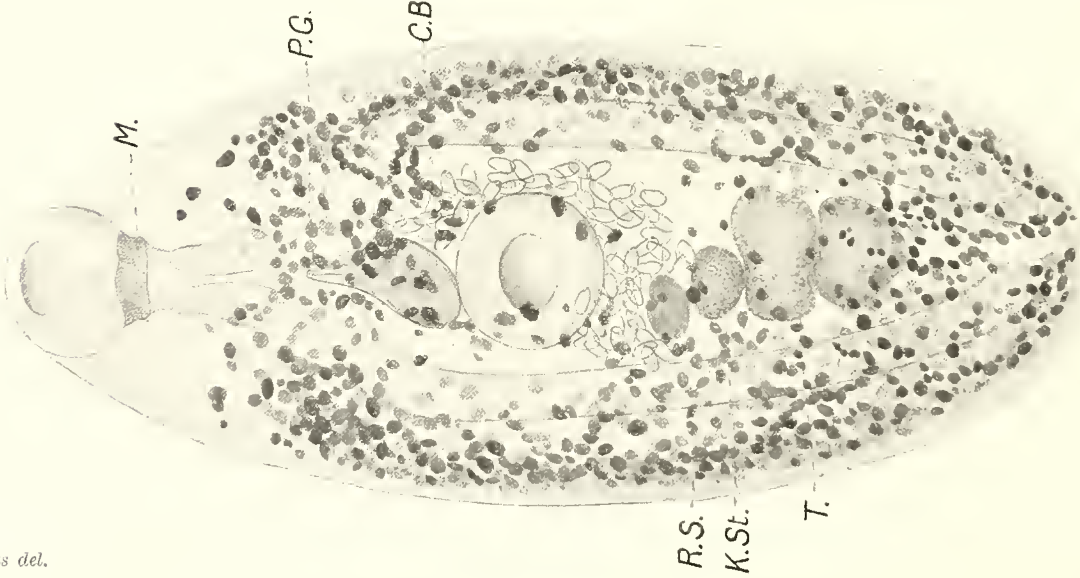


Fig. 1

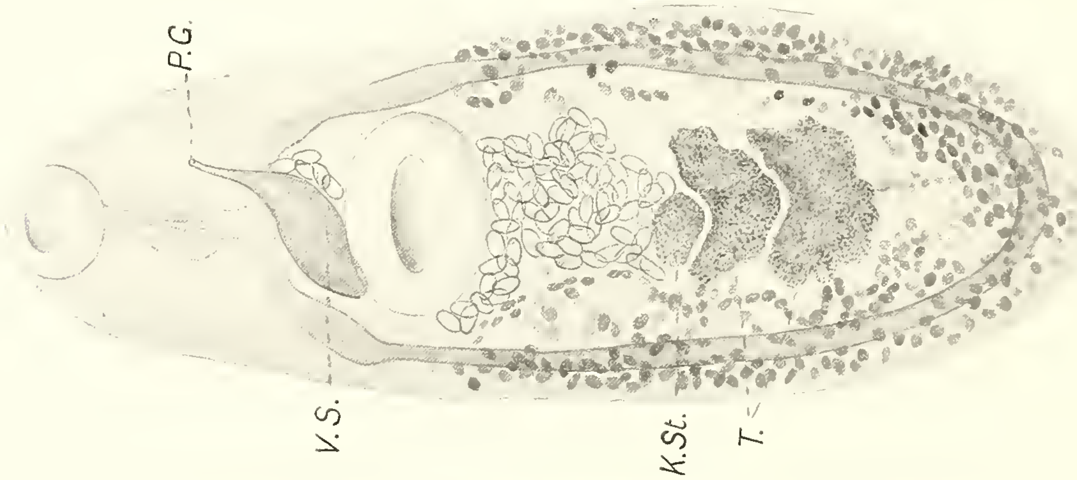


Fig. 2

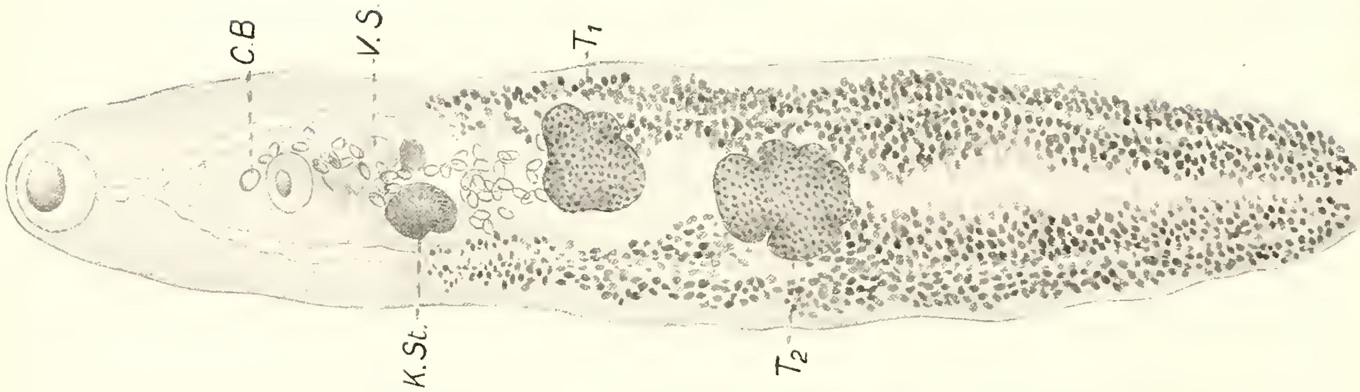


Fig. 3

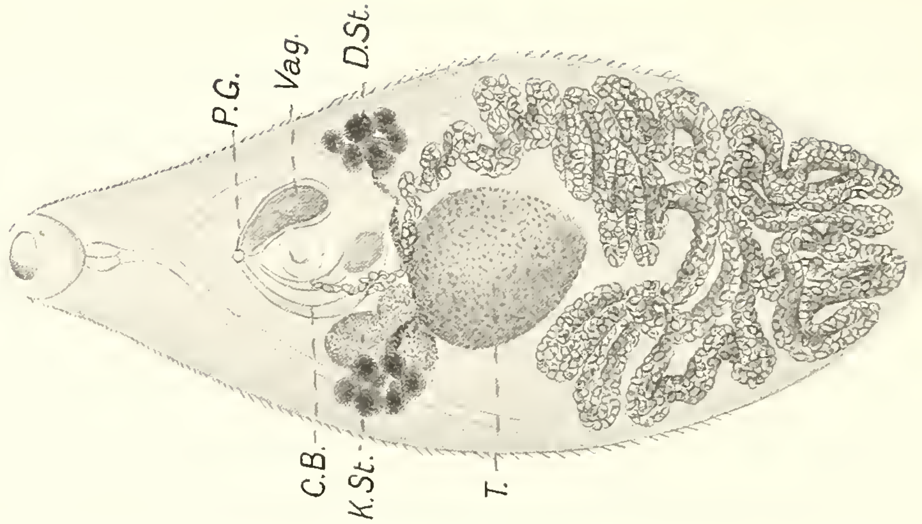


Fig. 4

G. Roberts del.

PLATE IV

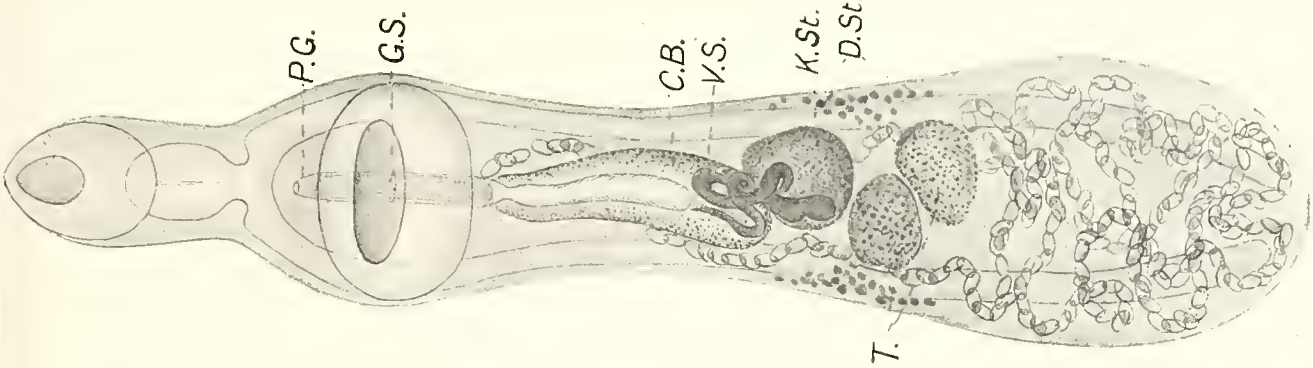


Fig. 8

Fig. 7

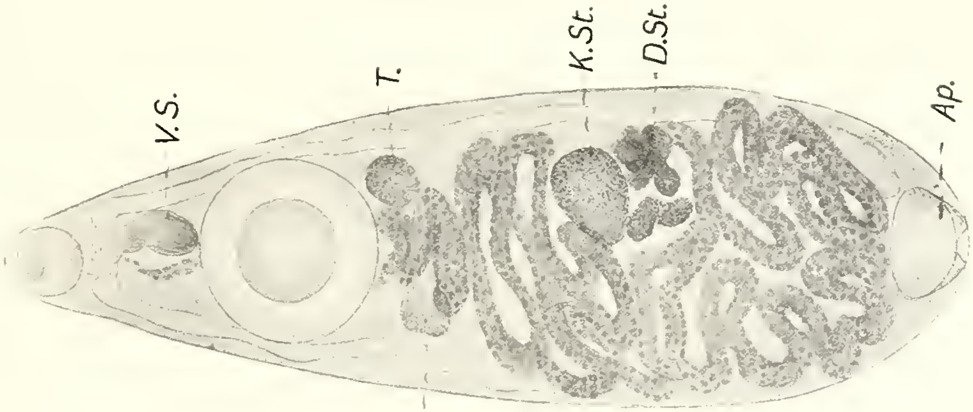


Fig. 6

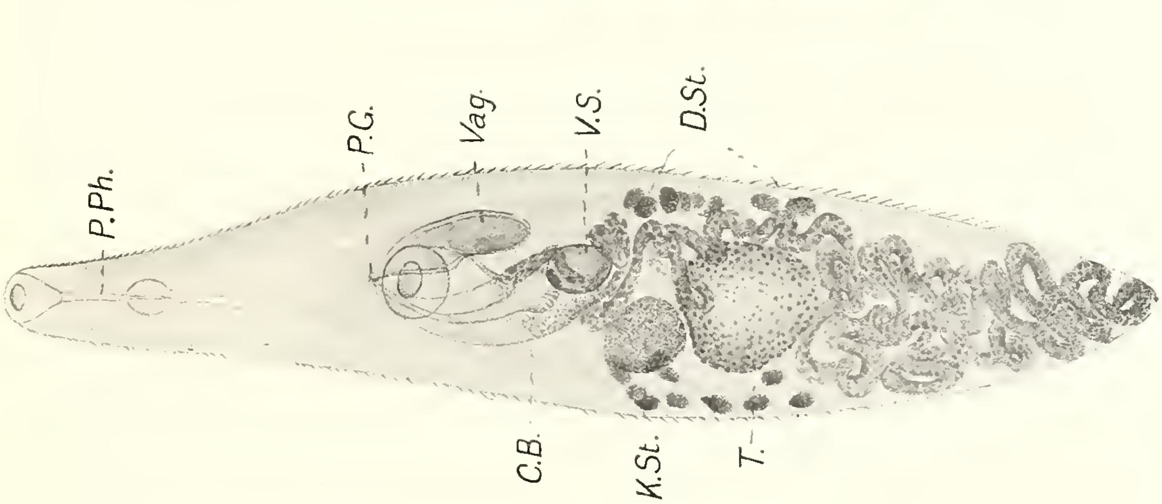


Fig. 5

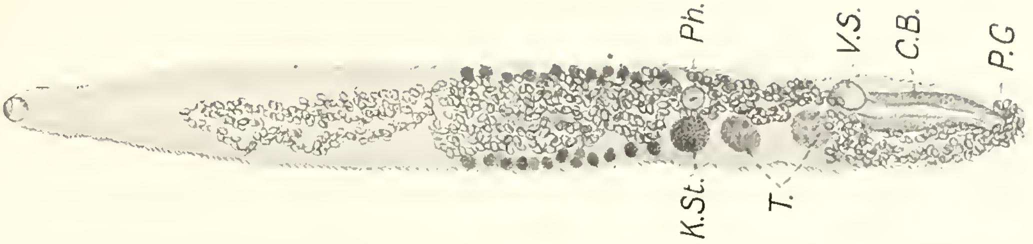


Fig. 11

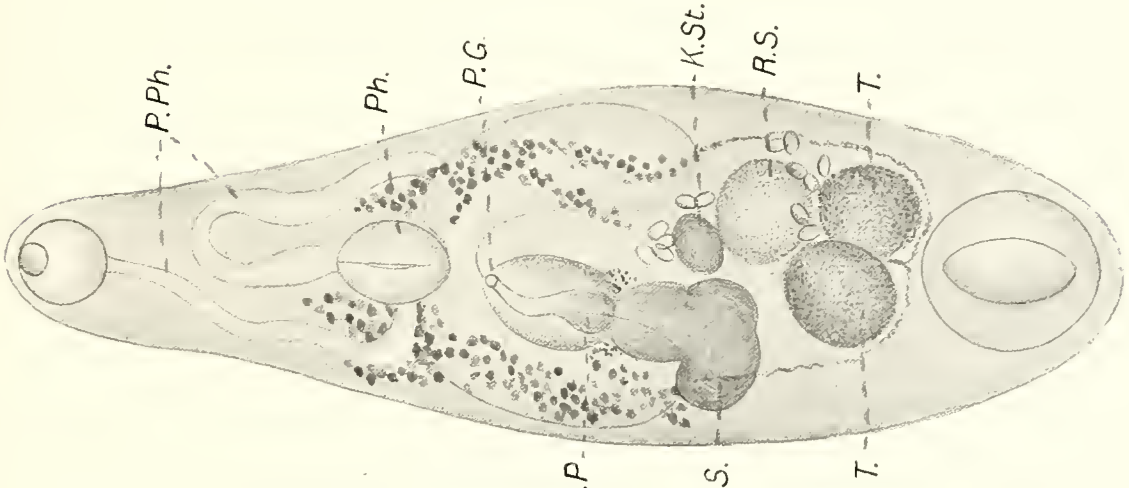


Fig. 10

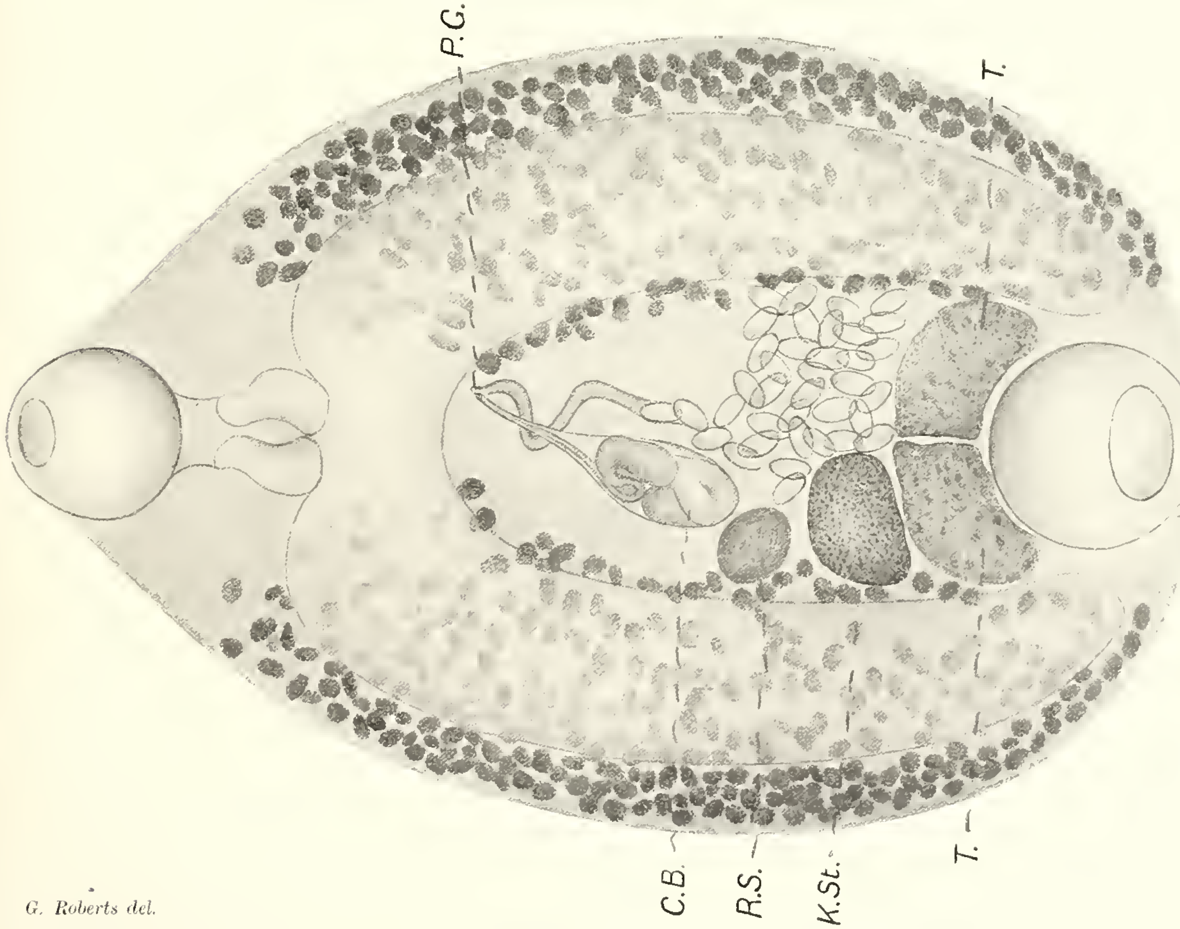


Fig. 9

G. Roberts del.

EXPLANATION OF PLATES IV AND V.

Fig. 1. *Maculifer sub-aequiporus.* ×30.
„ 2. *Coitocoecum gymnophallum.* ×40.
„ 3. *Aephnidiogenes barbarus.* ×30.
„ 4. *Genolopa trifolifer.* ×50. Pressure preparation.
„ 5. *Genolopa cacuminata.* ×60.
„ 6. *Sterrhurus brevicirrus.* ×50. Pressure preparation.
„ 7. *Ectenurus angusticauda.* ×30.
„ 8. *Xenopera insolita.* ×60.
„ 9. *Opistholebes amplicoelus.* ×70. Pressure preparation.
„ 10. *Gyliauchen tarachodes.* ×40.
„ 11. *Bucephalopsis exilis.* ×50.

All the figures are drawn from the ventral surface.

The following letters apply to all the figures:

Ap.	Appendix	*P.G.*	Genital aperture
C.B.	Cirrus-pouch	*P.P.*	Pars prostatica
D.St.	Yolk glands	*P.Ph.*	Prepharynx
G.S.	Genital sinus	*R.S.*	Receptaculum seminis
K.St.	Ovary	*T.*	Testes
M.	Muscular part of prepharynx	*Vag.*	Vaginal sac
		V.S.	Vesicula seminalis

A NEW SPECIES OF TAPEWORM FROM A PARAKEET, *BROTOGERYS TIRICA.*

By F. J. MEGGITT, M.Sc.,
Board of Agriculture and Fisheries Research Scholar,
University of Birmingham.

(With Plates VI and VII and 4 Text-figures.)

Introduction.

In the course of dissecting a parakeet (*Brotogerys tirica*) sent to me for examination, I came across several large tapeworms of the genus *Cotugnia* in the duodenum. They did not agree with any of the species previously described and, upon closer examination, showed so many points of difference as to justify the creation of a new species for them. I propose the name *Cotugnia brotogerys* for this species.

The genus *Cotugnia* was created by Diamare (2) for those avian Cestodes which have a double set of male and female reproductive organs in each proglottis, and a rostellum armed with T-shaped hooks. It is distinguished from *Dipylidium*, the only other avian tapeworm with double reproductive organs and an armed rostellum, by this latter character. Its distribution is chiefly African, but it has also been found in North and South America: it is possible that it is also present in Europe as one of its hosts, *Columba*, is found there. Seven species are known, occurring in the cassowary (*Dromacus*), sand grouse (*Pteroclus coronatus*), parakeet (*Brotogerys, Palaeornis*), turtle-dove (*Columba turtur*), fowl (*Gallus gallus*), and *Numida rikwae.*

In order to indicate clearly and accurately the difference between the new species and the six species previously described, I have drawn up a table (Table A) giving the character of each species according to its proposer.

It may be seen that the descriptions of two, *Cotugnia inaequalis* and *Cotugnia digonopora,* of these six species cannot be regarded as sufficient to establish the identity of the species. The latter has not yet had the

TABLE A.

Cotugnia	Muscles	Cirrus-sac	Testes	Ovary	Yolk-gland	Receptaculum seminis
C. browni Smith (7)			Six or more in the anterior part of the segment.	"rosette-shaped"		spherical
C. brotogerys n. sp.	3 layers of transverse muscles	does not reach longitudinal excretory vessel	extend across whole median field : in two layers, transversely	strongly lobed	not lobed, posterior to ovary	spherical
C. collini Fuhr. (3)		does not reach longitudinal excretory vessel	sharply divided into two groups, right and left: in one layer transversely	strongly lobed	not lobed, posterior to ovary	spherical
C. crassa Fuhr. (3)	3 layers of transverse muscles		extend across whole median field: in three to four layers transversely	weakly lobed	external to ovary	spindle-shaped
C. digonopora Pasq. (6)		reaches longitudinal excretory vessel	extend across whole median field			
C. inaequalis Fuhr. (3)						spindle-shaped
C. polycantha Fuhr. (3)	4 layers of transverse muscles	does not reach longitudinal excretory vessel	sharply divided into two groups: several layers transversely	strongly lobed	lobed, posterior to ovary	

reproductive organs properly investigated and rests upon external characters and measurements: the former, of which only one specific character (the shape of the receptaculum seminis) is given, was described from two greatly macerated specimens without heads. Since, as far as I could ascertain, no complete account of any species of this genus has been given, I have endeavoured to make the following description embrace as many points as possible.

I wish here to express my thanks to Mr W. H. Edwards, Curator of the Birmingham Natural History Museum, for identifying the parakeet submitted to him, and to acknowledge my indebtedness to Professor Gamble, F.R.S., for the help he has given me in the elucidation of some of the more dubious points in the anatomy.

Occurrence.

The specimens were obtained from the duodenum of a parakeet, *Brotogerys tirica*, which they nearly filled: their heads lay freely in the lumen without any attachment to the intestinal walls: this was probably owing to conditions produced by the death of the host, for in the cavities of the suckers were fragments of tissue recognisable as portions of duodenal villi. The host came originally from Brazil, but had been in England about six months. As it was fed upon purely vegetable food, the tapeworms must have been introduced when in Brazil, and have developed since. This is only the second record of a *Cotugnia* from America, and the first from South America. The effect of the parasite upon the host was to cause slow starvation, the bird being very emaciated and especially thin upon the breast.

External Characters.

The length of adult specimens of this species is approximately 75 mm. and the maximum width 2 mm. The head (Pl. VI, fig. 1) is nearly spherical, being 0·45 mm. long and 0·42 mm. wide. It is provided with four suckers with a diameter of 0·081 mm., and a well-developed apical rostellum. The latter is armed with a double row of hooks, 0·012 mm. long, of the characteristic *Davainea* type (Text-fig. 1); the shape

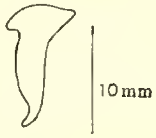


Fig. 1.—Hook from rostellum.

of the hooks however cannot be seen until the head is teased apart and the hooks spread out. Surrounding the rostellum is a thick ridge within which it may be retracted.

The rostellum itself (Pl. VI, figs. 1 and 4) is small in comparison with the size of the head. Its length is 0·0462 mm. and its diameter 0·15 mm. It consists of a simple apical protuberance composed of the usual parenchyma, bearing the double circle of hooks just mentioned and surrounded by a circular ridge (*r.r.*). In the centre of the protuberance is a hemispherical core (*r.c.*), 0·074 mm. in diameter and 0·0247 mm. long, having a slightly muscular appearance. I am in doubt as to the function of this core. At no point does it reach the exterior, so that it cannot be used for purposes of fixation: it is certainly not sufficiently muscular to be used for the protuberance of the rostellum, and furthermore is surrounded by a very definite membrane so that muscles cannot penetrate to its interior. Lack of material and the consequent lack of preparations makes it impossible to proceed any further in the elucidation of this organ.

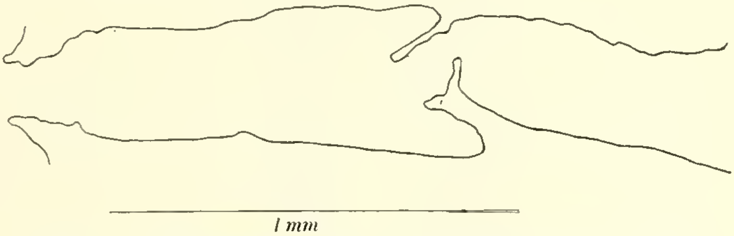


Fig. 2.—Longitudinal vertical section through a proglottis.

Anteriorly, the proglottides are many times wider than long, but more posteriorly their length increases more rapidly than their width. Mature proglottides measure 1·546 mm. long × 1·774 mm. wide, and proglottides ready for detaching are 1·7166 mm. long by 2·566 mm. wide. The posterior edge of each proglottis overlaps the anterior margin of the succeeding one, slightly at first, but to an ever increasing extent posteriorly (Text-fig. 2).

Musculature.

The musculature consists of three distinct layers of longitudinal muscles alternating with three layers of transverse muscles, the innermost layer being transverse. In the more posterior part of the proglottis, the muscles, more especially the longitudinal ones, are surprisingly feebly developed: in proportion as sections are taken anteriorly, they increase in size, and in the scolex are relatively large. They are never as numerous and occupy as much room as those described for the other species of this genus. In the scolex, a number of the longitudinal muscles bend outwards and, splitting at their distal ends, attach themselves at several places to the inner surface of the suckers: in this way the suckers are covered with a fine muscular network internally. The majority however proceed anteriorly without touching the suckers and attach themselves to the outer margin of the rostellum: a few run more internally and become fixed to the corresponding margin of the rostellar core.

Excretory System.

The excretory system (Text-fig. 3) consists of the usual four longitudinal vessels running the whole length of the strobilus and following

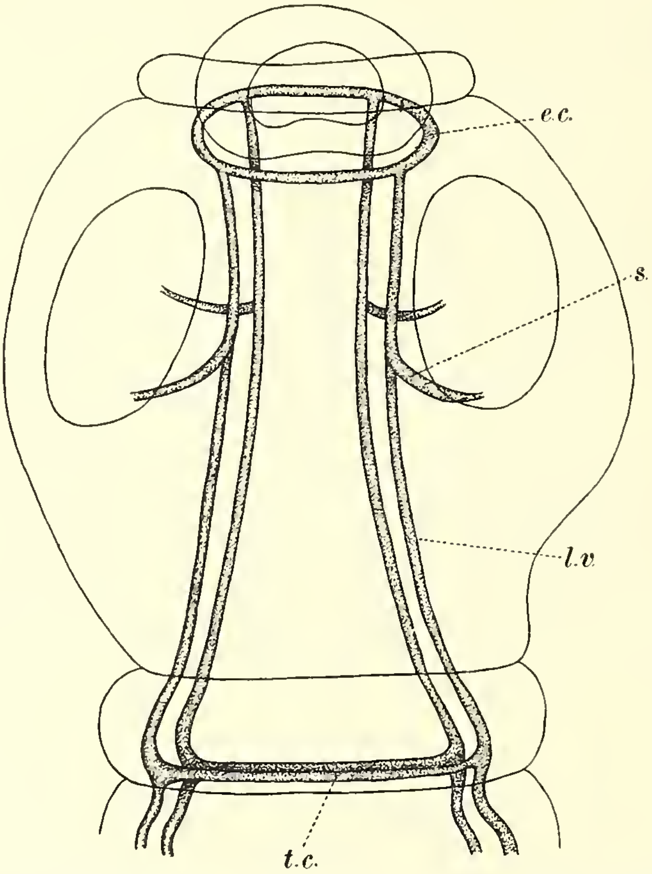


Fig. 3.—Reconstruction of the excretory system in the scolex. *e.c.* Anterior excretory commissure. *l.v.* Longitudinal excretory vessel. *s.* Branch of excretory vessel to suckers. *t.c.* Transverse excretory commissure.

its outline, *i.e.* at every junction between two proglottides they curve towards the interior, to bend outwards again directly the junction is passed: their course is therefore like a spiral in one plane. Near the posterior border of each proglottis, the two dorsal vessels and the two ventral ones communicate by transverse commissures: the commissures have the same diameter as their respective longitudinal vessels. There are not, as far as could be ascertained, dorso-ventral commissures connecting the dorsal and ventral vessels of the same side. In the scolex, the dorsal and ventral vessels have the same diameter, 0·0056 mm.: more posteriorly, the ventral vessel increases greatly in size while the dorsal gradually diminishes, until in proglottides in which the genital organs are mature there is only a ventral vessel, the dorsal having completely disappeared. The ventral vessel continues to increase in size as far as the posterior end of the strobilus, attaining a size of 0·18 mm. by 0·08 mm.

In the scolex, the four vessels empty into a circular commissure (*e.c.*) just posterior to the rostellum and anterior to the suckers: from this, several branches run to the rostellum. At the level of the posterior third of the suckers, each longitudinal canal gives off a branch to the posterior border of the corresponding sucker (*s.*). In addition to this definite excretory system, numerous fine branches, too minute to be traced, radiate in all directions from the longitudinal vessel and the commissure, forming an elaborate and extensive plexus.

Nervous System.

The nervous system (Text-fig. 4) consists of two longitudinal nerve trunks, running the whole length of the strobilus and following its outline like the longitudinal excretory vessels, and a central nerve mass under the rostellum. Throughout their entire course, the longitudinal nerve trunks give off minute branches which disappear in and apparently fuse with the surrounding parenchyma. In the scolex they bend interiorly, passing internally to the suckers but externally to the excretory vessels. At about the anterior level of the sucker openings, the two trunks bend inwards and run transversely across the scolex to meet and fuse in the centre (*b.*). The transverse portion is much larger, but at the same time, less compact than the longitudinal trunks. Just posterior to this central "brain," each longitudinal trunk gives off two lateral branches (*s.n.*) which curve anteriorly, transversely, and then posteriorly to the corresponding suckers. The central "brain" gives off at each lateral extremity an anterior branch (*l.*): this divides into two almost immediately. The more interior branch (*l′*) goes straight to the core found in the rostellum and reaches it almost at its lateral side: here it disappears. The remaining branch (*l″*) skirts the rostellar core just mentioned and bends round anteriorly to this to enter the centre of the rostellum.

Genital Organs.

In each proglottis are two complete sets of genital organs, the ducts from which open on the opposite sides of the segment (Pl. VI, fig. 3). The genital pores are dorso-lateral and are situated at the anterior third of the segment. There is a common genital sinus running 0·102 mm. into the proglottis. It has a short ventral course and then a longer transverse one. Into the bend marking the junction between

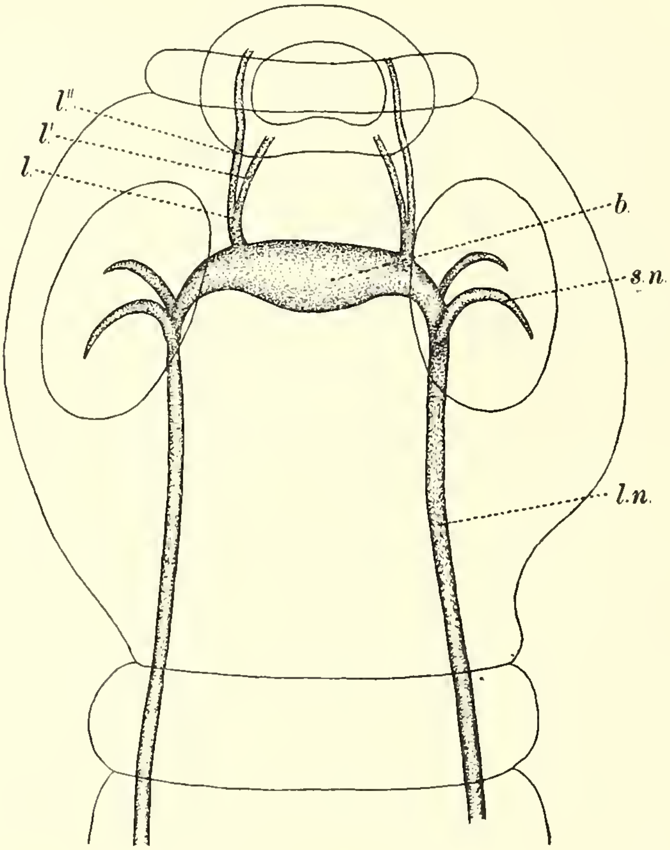


Fig. 4.—Reconstruction of the nervous system. *b*. Anterior nerve mass. *l*. Anterior lateral nerve. *l′*, *l″*. Its two branches. *l.n*. Longitudinal nerve. *s.n*. Nerve to sucker.

the two courses opens the cirrus: the vagina does not enter it until its extreme inner end. The openings of the male and female ducts are in the same horizontal plane.

Male Organs.

With the exception of a narrow anterior strip, the testes occupy the whole of the middle field of each proglottis (Pl. VI, fig. 3). They lie in two layers half-way between the dorsal and ventral surfaces, and extend laterally beyond the longitudinal excretory canal: they are most numerous in the centre of the segment. Each testis is surrounded by a thin but distinct tunica propria, which at one point is drawn out into a fine duct, connecting the testis with the nearest vas efferens. The vasa efferentia of the one side join together at about one-third the width of the proglottis (Pl. VI, fig. 5) and midway between the anterior and posterior borders to form a slender vas deferens. They are extremely slender muscular tubes and their small size in view of the large size of the spermatozoa is surprising: their walls must obviously be capable of great expansion in order to allow of the passage of the male elements.

The vas deferens (*v.d.*) runs at first towards the lateral margin but later bends round in a sweeping curve so as to point towards the anterior border. It increases considerably in size, having a diameter of 0·048 mm., and presents the appearance more of a vesicula seminalis than of a duct (*v.s.*). It bends round, running posteriorly for a short distance, but just posterior to the cirrus-sac it bends anteriorly again and after a short course runs laterally to open into the cirrus-sac. From the time it runs posteriorly to the time it enters the cirrus-sac, its diameter decreases gradually, until at the latter point it is only 0·011 mm. During the whole of its course it only occupies the middle third of the proglottis. There is no vesicula seminalis, the enlarged portion of the vas deferens taking its place.

The cirrus-sac itself is an oval elongated organ lying near the anterior margin of the proglottis and near its dorsal surface. In some proglottides it appears to extend internally as far as the longitudinal excretory canal, but in the majority of cases it does not reach as far. At its outer end it bends towards the dorsal surface, the amount of the bend varying in different proglottides. The course of the vas deferens in the cirrus-sac is fairly straight, the few bends present appearing to be due to contraction caused by fixation. Its opening into the genital cloaca has already been described. Unfortunately, owing to some unknown cause, none of the specimens contained a well-preserved cirrus, so that it is impossible accurately to figure it. Its distal end was evidently enlarged into a small thickly nucleated knob, 0·0095 mm. in diameter. In the majority of cases this knob was plainly to be seen: its junction with the vas deferens however had degenerated into a mere strip of structureless tissue.

Spermatogenesis.

The testes first appear as small groups of nucleated cells 0·003 mm. in diameter, surrounded by a thin but distinct membrane (Pl. VII, fig. 3). There does not appear to be any trace of the endogenous division described by von Linstow (4) and Moniez (5): as far as could be ascertained with a magnification of approximately 1500, the divisions were amitotic and the products separated almost immediately afterwards. This is in accordance with Child's (1) account.

After they have reached their full size, the large spherical cells (spermagonia) just mentioned become aggregated into groups (Fig. 4). The inner side of each cell then elongates, forming a long point directed towards the interior of the group, the nucleus of the cell remaining in the outer hemispherical portion. A roughly spherical cluster of conical cells is thus produced, the inner and narrower ends of the cells just touching (Fig. 5).

Fusion of the cell cytoplasm next occurs at the point of contact (Figs. 6 and 7) and continues until all the cells have coalesced to form a sphere (cytophore) of varying size, the exterior of which still shows traces of its original components in the form of numerous small blisters, these being the parts of the cells remaining unabsorbed. Nuclear changes, which I have not been able to follow, next occur, resulting in a considerable diminution in the size of the nuclei and an increase in their number. During this process they remain near the periphery of the cytophore (Fig. 8).

The cytophore now splits internally in such a way as to separate an inner sphere (blastophore) from an outer envelope (Fig. 10). Both grow rapidly in size. At a certain point the cytoplasm of the outer sphere becomes segregated out round the nuclei. These latter now become the centres of small separate masses of cytoplasm, each nucleus being surrounded by a definite and equal amount. Small uninucleated bodies, radially elongated, are thus formed, attached at their narrower ends to the still undifferentiated blastophore (Figs. 11, 12). These round themselves off into small spheres and, congregating upon the surface of the blastophore, give rise to a "morula" stage (Fig. 13). They then pursue one of two courses. They may remain attached by a narrow protoplasmic strand to the blastophore and grow considerably in size, or they may be entirely constricted off and lie freely in the cavity of the testis. In either case a considerable augmentation in size is observable.

After a certain period of growth formation of spermatozoa begins. In this process the nucleus fragments, small pieces of chromidia become scattered throughout the cell and gradually diminish in size and number (Figs. 15 and 16). I have not been able actually to observe the formation of a spermatozoön, the next stage seen being one in which the tail has already been partially formed and is attached at one end by a delicate fibre transversing the cytoplasm to one of the chromatin granules previously mentioned (Fig. 17). It seems possible that the tail is formed by the separation and differentiation of the portion of the cytoplasm between the chromidial fragment and the exterior of the cell. This stage, together with fully formed spermatozoa and still undifferentiated spermatids, is frequently found in the receptaculum seminis. The fully developed spermatozoön has a small distinct spherical head and a comparatively long tail curved and flexed (Fig. 18).

The preceding account agrees as a whole with that given by Child (1) for *Monezia*, the chief difference being his omission of any statement regarding the presence and origin of the blastophore. In his account the cytophore usurps its function. There is also a difference in the behaviour of the spermatids. In *Monezia* they are apparently never separated from the cytophore but while attached form the spermatozoa; in *Cotugnia*, on the other hand, they may lie freely in the cavity of the testis or even penetrate into the receptaculum seminis before producing spermatozoa: in any case their connection is much slighter than in *Monezia*.

In general outline an agreement with von Linstow's (4) account of spermatogenesis in *Anomotaenia constricta* Molin can be perceived. He certainly describes the spermatocytes ("Tochterzellen") as being produced endogenously within the spermagonium ("Mutterzelle"), and asserts that all further processes occur within its limits, but the fusion of the spermatocytes to form cytophores ("Tochterzellen zweiter Generation"), their division into "Enkelzellen" from which the spermatozoa are produced, and the formation of the spermatozoa themselves occur in almost identically the same manner as the corresponding processes in *Monezia* and *Cotugnia*. The only discrepancy is that the blastophore ("Stemmzelle") is said to be a spermatocyte which undergoes no further differentiation.

Moniez's account (5) differs from the three preceding in that it asserts that the spermatocysts separate and do not fuse, each single cell growing and producing endogenously spermatids which in their turn form the spermatozoa. It also omits any mention of a blastophore.

From the above four accounts, that of Child for *Monezia*, of von Linstow for *Anomotaenia constricta*, of Moniez, and of myself for *Cotugnia*, a general account of the development of spermatozoa in the Cestoda can be compiled. The initial spermagonium in all cases forms several spermatocytes, either endogenously or by continued division of its products. In three of the cases these spermatocysts fuse to form cytophores; in the fourth no fusion occurs. Again, all four accounts state that these cytophores divide, forming spermatids ("Enkelzellen"), which in their turn produce spermatozoa. In two cases a blastophore is present derived from the daughter-cells (*a*) by growth of a single daughter-cell as in *Anomotaenia*, (*b*) by division of a cytophore as in *Cotugnia*. It is therefore evident that in Cestodes there is a general agreement with regard to the course taken by spermatogenesis in its broad outlines. The discrepancies, which undoubtedly exist, do not affect the general plan of the course taken, and may be partially accounted for by failure in technique and differences in the material used.

Female Organs.

The vagina is continuous with the extreme inner end of the genital cloaca (Pl. VI, fig. 3). There is no sphincter muscle. After its junction with the cloaca, the vagina runs postero-transversely slightly towards the dorsal surface, bends once or twice, and then opens into the antero-lateral end of a spherical receptaculum seminis. This latter is 0·067 mm. in diameter, with a wall 0·0033 mm. thick, and is usually filled with a congested mass of spermatozoa. It lies near the dorsal surface of the proglottis, at about the anterior third of its length. The lumen of the vagina is slightly constricted as it opens into the receptaculum seminis.

The opposite end of the receptaculum seminis opens, rather posteriorly, by means of a short duct into a non-ciliated oviduct (Pl. VI, fig. 6; Pl. VII, fig. 19). Its ventral portion (*v.ovd.*), 0·0167 mm. in diameter, runs anteriorly and ventrally to open after a short course into the ovary. There is no oöclapt, a slight swelling of the oviduct at its junction with the ovary taking its place. The ovary itself is a strongly lobed organ consisting of a number of short thick lobes radiating from the segment of a sphere, the lobes being 0·08 mm. long, and the concave base from which they extend 0·24 mm. in diameter. It lies on the ventral surface of the proglottis at approximately the anterior third of its length.

The dorsal portion of the oviduct (*d.ovd.*) runs at first anteriorly, but quickly bends posteriorly and turns with successive sudden curves first laterally, then dorsally, and finally dorso-laterally, running towards the interior of the proglottis. During this part of its course it diminishes greatly in size, being only 0·0085 mm. in diameter, and has its lumen nearly obliterated. After a short course it receives the yolk-duct, 0·0095 mm. in diameter. The yolk-gland (*y.g.*) to which the duct leads is a slightly lobed organ, 0·113 mm. wide by 0·066 mm. long, formed by the agglomeration of a number of follicles round a cavity. Each follicle consists of a matrix of cells having very pronounced nuclei and, in the majority of cases, their cell limits obliterated. The cavity they surround is eccentric in position, being slightly nearer the side on which the vitelline duct opens: it is lined by a definite membrane which is, however, liable to be absent from it in parts. The yolk-gland itself lies slightly posterior to the receptaculum seminis, but in the same horizontal plane, about one-quarter of the distance between the two lateral margins.

After its junction with the vitelline duct, the oviduct passes into the oötype, a small spherical dilation, 0·0167 mm. long by 0·0117 mm. wide, surrounded by the shell-gland. The latter is comparatively large, and is composed of long club-shaped or cylindrical cells with intensely staining nuclei. These cluster round the oötype, radiating out from it in all directions. From this point onwards, the lumen of the oviduct decreases and its wall thickens. It continues to run interodorsally for a short distance, but after a quick turn and a short course laterally, it bends abruptly upon itself to run anterior to the oötype nearly to the anterior margin of the proglottis, about one-third of the distance between the two lateral margins. Here it opens into the uterus (*ut.*). The uterine walls are much folded, forming many pockets, and have many outgrowths. They are thickly nucleated and are surrounded by glandular cells similar to those found along the course of the vagina. This glandular part is rather small and opens at its extreme anterior end into a narrow thin-walled passage, the uterus proper. In segments in which the genital organs are functional, it is only thus represented: in older segments it may be seen however that, while the glandular part of the uterus still persists, the more anterior narrow duct increases in length and gives off many outgrowths. These latter increase in size until in segments nearly ready for detachment, the uterus is a deeply lobed organ, filling nearly the entire proglottis. In older segments, these outgrowths assume a moniliform appearance, and gradually become constricted into isolated pockets each containing several ova.

Specific diagnosis.

Cotugnia: 75 mm. long by 2 mm. broad. Head: 0·42 mm. in diameter, 0·45 mm. long, with retractile rostellum 0·15 mm. in diameter, armed with a crown of numerous hooks arranged in a double row. Hooks as in Text-fig. 1, 0·012 mm. long. Suckers oval, unarmed, 0·081 mm. in diameter. Neck absent. Segments trapezoidal and imbricate. Genital organs double in each segment, genital pore situated at the anterior third of the lateral margin. Male and female canals pass dorsal to the excretory system.

Musculature: Three longitudinal muscle layers alternate with three transverse layers.

Male genitalia: Testes numerous in a double row, occupying the centre of the proglottis and extending laterally beyond the excretory canals. Cirrus pouch not reaching the longitudinal excretory canal.

Female organs: Yolk-gland posterior to ovary. Receptaculum seminis spherical. Ovary strongly lobed. Yolk-gland compact, little lobed. No persistent uterus present. Eggs enclosed in parenchymatous capsules, each containing several eggs. Egg has three membranes.

Life history: Unknown.

Host: *Brotogerys tirica.*

Locality: Brazil.

REFERENCES.

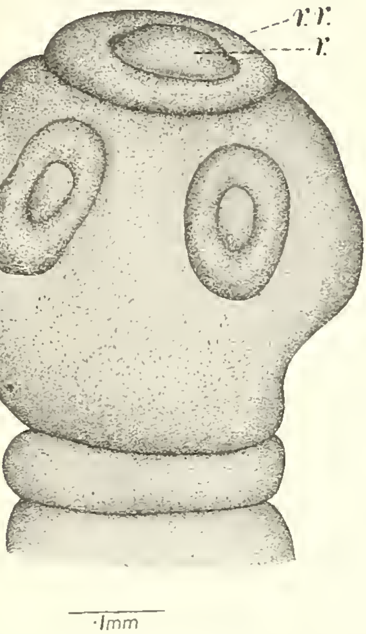
(1) Child, C. H. (1907). Development of the Spermatogenesis in *Monezia*. *Biol. Bull. Woods Holl,* xii. 175–191.

(2) Diamare, V. (1893). Note su Cestodi. *Boll. della Soc. di Natur. in Napoli,* Ser. 1, vii. 10.

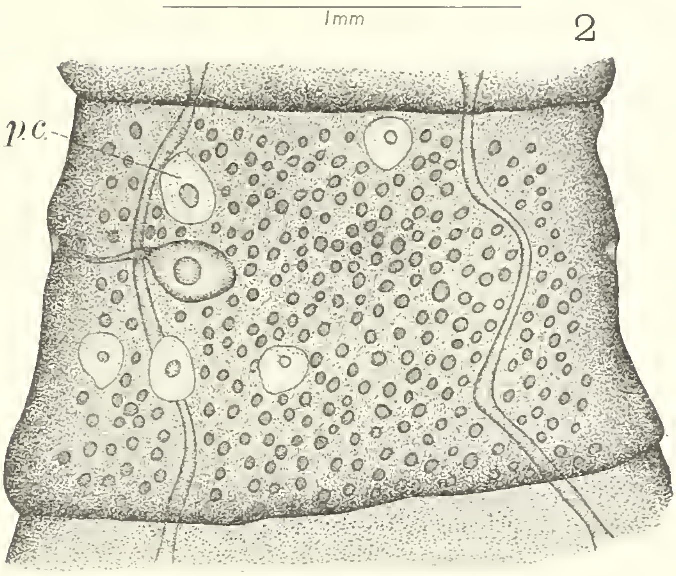
(3) Fuhrmann, O. (1909). Neue Davaineiden. *Central. f. Bakt. u. Parasitenk.,* 1 abt., xlix. 116.

(4) von Linstow (1890). Beitrag zur Kenntniss der Vogeltaenien nebst Bemerkungen über neue und bekannte Helminthen. *Arch. f. Naturgesch.* Jahrg. 56, vol. i. (quoted from M. Braun in H. G. Bronn's *Klassen und Ordnungen des Thier-Reichs,* p. 1404).

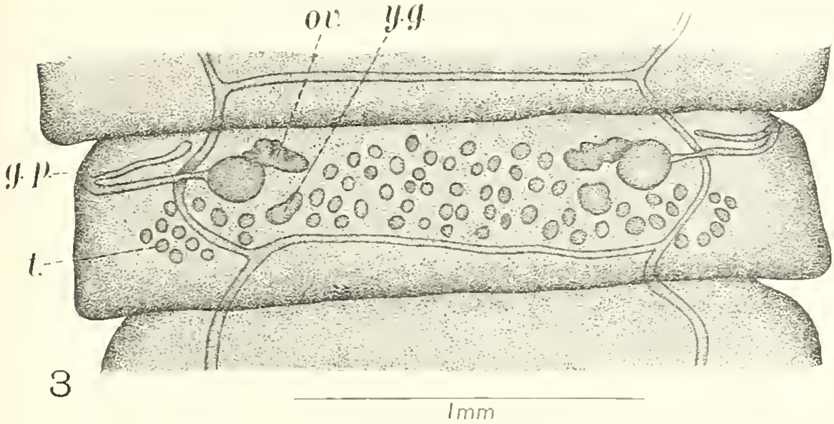
1


r.r.
r.
1mm

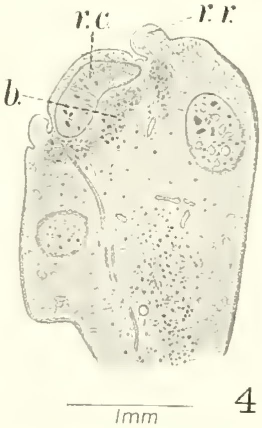
2


1mm
p.c.

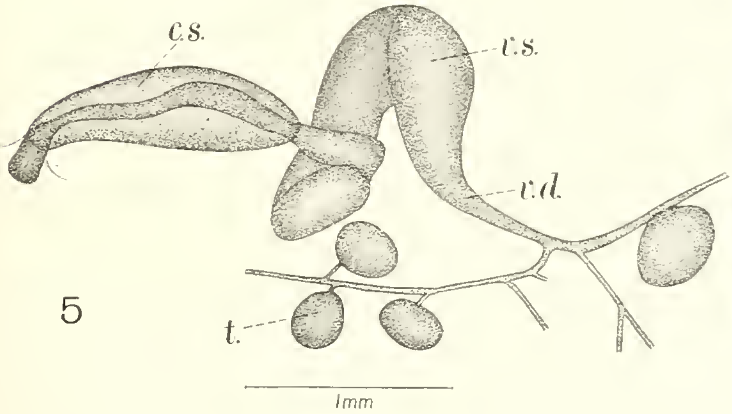
3


ov.
y.g.
g.p.
t.
1mm

4


r.c.
r.r.
b.
1mm

5


c.s.
v.s.
v.d.
t.
1mm

6

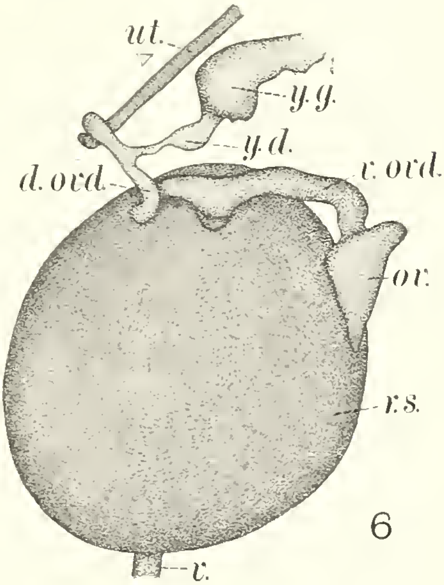
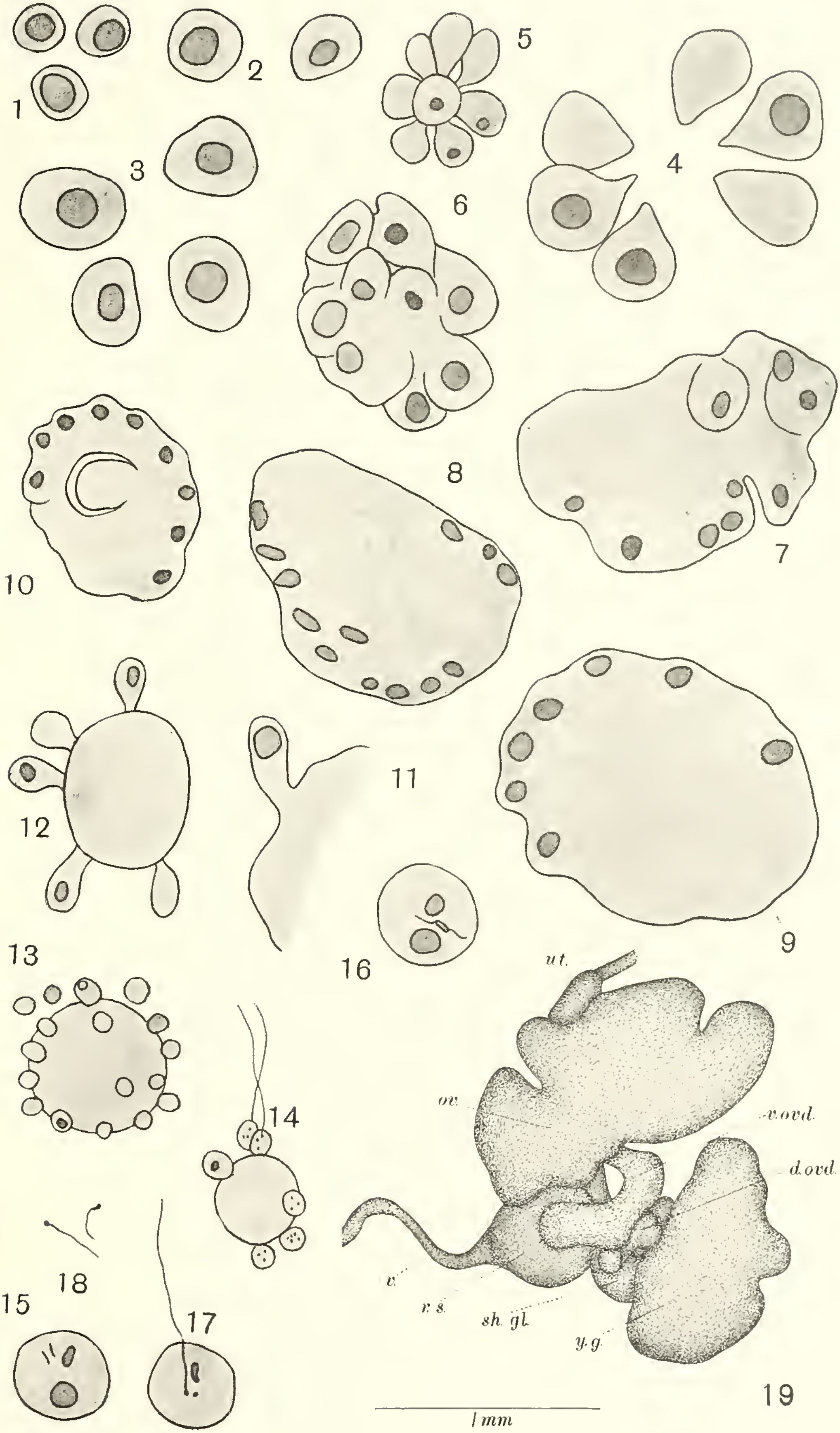

ut.
y.g.
y.d.
d.ovd.
v.ovd.
ov.
r.s.
v.

PLATE VII


1
2
5
4
3
6
7
8
10
9
11
12
16
13
14
15
18
17
19
ut.
ov.
v.ovd.
d.ovd.
v.
r.s.
sh. gl.
y.g.
1 mm

(5) MONIEZ, R. (1881). *Thèses* présentées à la Faculté des Sciences de Paris. Paris, 1881.

(6) PASQUALE, A. (1890). Le tenie dei polli di Massana. *Giorn. intern. sc. med. Napoli*, Ann. XII.

(7) SMITH, FOX and WHITE (1907–08). Contributions to Systematic Helminthology. *Univ. Penn. Med. Bull.*, XX. 283.

EXPLANATION OF PLATES VI AND VII.

REFERENCE LETTERS.

b. Anterior nerve mass. *c.s.* Cirrus sac. *d.ovd.* Dorsal portion of oviduct. *g.p.* Genital pore. *ov.* Ovary. *p.c.* Parenchymatous capsule. *r.* Rostellum. *r.c.* Hemispherical core. *r.r.* Rostellar ridge. *r.s.* Receptaculum seminis. *sh.gl.* Shell-gland. *t.* Testis. *ut.* Uterus. *v.* Vagina. *v.d.* Vas deferens. *v.ovd.* Ventral portion of oviduct. *v.s.* Enlarged portion of vas deferens. *y.d.* Yolk-duct. *y.g.* Yolk-gland.

PLATE VI.

Fig. 1. Scolex.
Fig. 2. Proglottis nearly ready for detaching.
Fig. 3. Sexually mature proglottis.
Fig. 4. Longitudinal section through scolex.
Fig. 5. Reconstruction of male reproductive system.
Fig. 6. Reconstruction of female reproductive system, from transverse sections.

PLATE VII.

Figs. 1–18 illustrate spermatogenesis.
Figs. 1–3. Cells of young testis, various sizes, × 2300.
Fig. 4. Cells ready for fusion, × 2300.
Fig. 5. A further stage, foreshortened view, × 1500.
Figs. 6–7. Two stages during fusion, × 1500.
Fig. 8. Later stage, cytophore after the nuclear stages, × 1500.
Fig. 9. Cytophore with budding spermatids, × 2300.
Fig. 10. Cytophore with developing blastophore, × 1500.
Figs. 11–12. Later stage of cytophore, × 2300, × 1800.
Fig. 13. "Morula" stage, × 1500.
Fig. 14. Developing spermatozoa, × 1500.
Figs. 15–18. Developing spermatozoa from the receptaculum seminis. Fig. 18 shows only the head ends of the spermatozoa, × 1500.
Fig. 19. Reconstruction of the female reproductive system from longitudinal horizontal sections.

EXPERIMENTAL DRUG TREATMENT OF EAST COAST FEVER OF CATTLE.

By GEORGE H. F. NUTTALL, F.R.S.

(*From the Quick Laboratory, University of Cambridge.*)

(With 1 Chart.)

The results obtained in the treatment of East Coast Fever have been uniformly negative. Nevertheless it appears desirable to publish the records of 18 experimental cases which we have treated with various drugs, since the negative evidence afforded may help other workers in the search for the remedy which we must hope will ultimately be found.

Trypanblue was found to be ineffective by Nuttall and Hadwen (v. 1909, *Parasitology*, II. p. 190), in one experiment the dye "exerted no effect whatsoever on the parasite." The record and chart of the case accompanies the paper by Nuttall, Fantham and Porter (9. II. 1910, *Parasitology*, II. pp. 329, 331, 332). A cow was infected by means of *Rhipicephalus evertsi* adults, she showed fever on the 14th day, and a few parasites were found in her blood 20 days after the ticks had been placed upon the animal. The trypanblue was given intravenously on the 21st (200 c.c. of 1 % solution), 22nd (200 c.c. of 2 % solution) and 23rd day (100 c.c. of 2 % solution), but the number of parasites steadily increased until the animal died. Negative results were subsequently obtained in a field trial conducted in South Africa. We have shown that trypanblue is an excellent remedy for piroplasmosis in dogs and cattle, and it has been found effective in biliary fever in horses. As the question is frequently asked "What is trypanblue?" I herewith append the formula ($C_{34}H_{24}N_6O_{14}S_4Na_4$; the tetrazo compound of toluidine and amidonaphtholsulphonate of sodium).

The drugs used in the experiments herein recorded were the following:

I. *Congo red* ("concentrated," obtained from Messrs Levinstein, Ltd., Blackley, near Manchester). It was used once, 70 c.c. of a

0·5 % solution being injected subcutaneously into Calf 8 (see protocol of Exp. I) before the parasites appeared in the animal's blood, Koch's "blue bodies" having, however, been found in gland smears coincidently with the onset of fever. The administration of this dye did not retard the appearance of the parasites in the blood. The dye was tried because it had been found by me to exert an effect on *Piroplasma canis* (*Parasitology*, II. p. 415).

I *a*. *Sodium salicylate* (10 %) + *Sodium bicarbonate* (1 %) in 100 c.c. of NaCl solution was subsequently injected intravenously into Calf 8 on three days, beginning on the second day after the appearance of the parasites in the blood, but the result was negative.

II–III. *Tryposafrol* (according to Prof. Brieger and Dr Krause, kindly supplied by the Aktien-Gesellschaft für Anilin Fabrikation, Berlin). This dye was given to two calves. In Exp. II it was given in daily doses ranging from 0·25 to 3 grammes dissolved in sugared water which the animal drank. Treatment began on the fifth day after the onset of fever and for six days before the parasites appeared in the animal's blood, and continued daily up to and including the day of death. The number of parasites in the blood remained small but they showed a definite increase in spite of treatment. In Exp. III the calf received the same treatment, the dose of tryposafrol being 0·25, rising to 1·5 grammes daily; treatment began on the day after the first parasites appeared in the animal's blood and was maintained to the end. The number of parasitized corpuscles steadily increased in spite of treatment. (See protocol on p. 63.) This dye was tried because of the claims made by Brieger and Krause that it exerted a curative effect in piroplasmosis of cattle and in trypanosomiasis. Our experiments with tryposafrol in relation to piroplasmosis and trypanosomiasis will be reported upon in a future paper.

IV. *Creosote* 0·2 c.c. + *Oleum copaivae* 3·7 c.c. in 3 % solution injected intravenously in seven daily doses of 5 c.c. beginning on the third day of fever and three days before the appearance of parasites in the animal's blood. No effect was exerted by the treatment (see protocol, p. 64). Creosote was chosen as a representative of antiseptic drugs belonging to the volatile aromatic series, being more powerfully antiseptic than carbolic acid and possessing greater penetrating power. The copaiva was added as a representative of the less irritant volatile oils with antiseptic properties.

V. *Arsacetin* (sodium-p-acetyl-aminophenylarsinate-acetylarsanilate. Obtained from Farbwerke vorm. Meister Lucius und Brüning, Hoechst a. M.) was given in doses of 2 to 5 c.c. of a 5 % solution, intravenously on seven alternate days. Treatment began on the day after the parasites appeared in the animal's blood. The drug exerted no effect, as will be seen by reference to the protocol on p. 65.

VI–VII. *Soamin* (sodium-para-amino-phenylarsonate. Obtained from Messrs Burroughs Wellcome and Co.). In Exp. VI 2·5 grammes dissolved in 12·5 c.c. of hot water and injected intramuscularly, whilst warm, on seven days. Treatment began on the day when parasites first appeared in the calf's blood. In Exp. VII a 2 % solution was injected intravenously in doses ranging from 3 to 13 c.c. following on the injection of 2 to 4 c.c. of a solution of eosin and sodium bicarbonate ($\frac{1}{2}$ a grain of each per c.c.). The treatment began on the fifth day after the parasites appeared in the calf's blood. In both experiments the drug exerted no influence on the progress of the disease. (See protocols, pp. 66, 67.)

VIII. "606": a single dose of 2 grammes was injected intravenously on the third day after the parasites appeared in the cow's blood. The drug did not produce any visible effect on the parasites and the animal died of East Coast Fever within 48 hours. (See protocol, p. 68.)

IX. *Emetine hydrochloride*, 1 % in NaCl solution was injected intravenously in doses ranging from 1 to 10 c.c. on nine successive days, beginning on the second day of the appearance of parasites in the calf's blood. The drug did not affect the course of the disease, the number of parasitized corpuscles in the peripheral blood mounted steadily until the animal died. (See protocol, p. 69.) The drug was used because of the favourable reports relating to its curative action in Amoebiasis.

X. *Mercury salicylate*, 1 % in 0·8 % NaCl solution was injected intravenously in doses ranging from 4 to 20 c.c. on nine days. Treatment was commenced two days before the parasites appeared in the animal's blood. The drug exerted no retarding effect upon the progress of the disease. (See protocol, p. 70.)

XI. *Mercury succinimide* ($Hg[C_2H_4(CO_2)N]_2$) in 3 % solution was injected intravenously in three doses of 2, 4 and 3 c.c. in as many days, beginning on the day when the first parasites appeared in minimal numbers in the calf's blood. The drug exerted no effect whatever. (See protocol, p. 71.)

XII–XIII. *Quinine bihydrochloride.* In Exp. XII the animal received on 14 successive days subcutaneous injections of 55 to 60 grains dissolved in 25 c.c. of water. Treatment commenced on the third day of the appearance of parasites in the animal's blood. In Exp. XIII quinine hydrochloride was given on five successive days followed by the bihydrochloride on seven out of nine days, the drug being injected intramuscularly. Treatment in this case began on the first appearance of parasites in the calf's blood. No effect was observable from the treatment. (See protocols, pp. 72–74.)

XIV. *Ethylhydrocupreine HCl*, 24 c.c. of an 8 % solution was injected subcutaneously on five successive days, beginning on the second day after the appearance of parasites in the calf's blood. The result was negative. (See protocol, p. 75.) This drug had been recommended because of its bactericidal effect in pneumococcus infections.

XV. *Ammonium fluoride*, 0·5 % in 0·8 % NaCl solution was injected in doses of 18 to 20 c.c. intravenously on nine successive days. Treatment began on the second day of the parasites appearing in the calf's blood. There was no observable effect. (See protocol, p. 76.) The trial of ammonium fluoride was suggested by its known inhibitive effect on bacteria producing lactic and butyric acid fermentation without interfering with the growth of yeast.

XVI. *Potassium iodide* in 25 % solution was injected intravenously on five successive days, the dose ranging from 20 to 40 c.c. Treatment commenced a day before the parasites appeared in the animal's blood but the result was negative. (See protocol, p. 77.)

XVII. *Calcium lactate* in 10 % solution was injected intravenously on seven successive days, the dose ranging from 3 to 5 c.c. Treatment began on the second day of the appearance of parasites in the calf's blood. There was no effect observable. (See protocol, p. 78.)

XVIII. *Nuclein* from thymus gland, 10 c.c. of a 5 % solution was given subcutaneously on five days, commencing on the third day of fever and two days before the parasites appeared in the calf's blood. The treatment was without effect. (See protocol, p. 79.)

Records of Cattle subjected to Drug Treatment.

When the experiments took place in winter the animals were kept in stalls warmed to 60–70° C. The ticks used for infecting the animals were enclosed in bags fastened about the ears of the cattle.

Blood films were prepared from the animals every day from the time that fever occurred. In some cases films were prepared twice a day or oftener. The films were stained by Giemsa's method. To determine the percentage of infected red blood corpuscles it was usually found sufficient to count 250 corpuscles all told (infected and uninfected), but on some occasions 500 to 1000 were counted so as to arrive at a more exact result.

Autopsies were made and the presence of typical lesions was noted in all cases.

EXPERIMENT I (*Calf* 8).

Treatment: (1) *Congo red*, 0·5 % solution, 70 c.c. injected subcutaneously on the 14th day.

(2) *Sodium salicylate*, 10 % solution + *Sodium bicarbonate*, 1 % in normal NaCl solution, 100 c.c. injected intravenously on the 21st, 22nd and 24th day.

(3) *Mercury salicylate* in 1 % solution, 5 c.c. injected intravenously on the 29th day (too late).

Date 1911	Day	Temp. °F		
		a.m.	p.m.	
11. x.	1	—	101·4	12 infected *R. appendiculatus* adults (6 ♂, 6 ♀) were placed on the calf
	2	101·2	101·8	
	3	101·4	101·2	
	4	101·4	101	
	5	101·2	101·4	
	6	100·8	101	
	7	101·8	101·2	
	8	100·6	101·4	
	9	101·8	—	
	10	102	102	
	11	102	—	
	12	102	—	
	13	102·6	—	

EXPERIMENT I (*cont.*).

Date 1911	Day	Temp. °F. a.m.	p.m.		*Treatment*
24. x.	14	104		Fever begins. Koch's "blue bodies" found in gland smear.	
			104·8		*Treatment*: 70 c.c. 0·5 % Congo red, subcutaneously
	15	103·4			
			—		
	16	103·6			
			106·4		
	17	105·2			
			105·4		
	18	104·6			
			105		
	19	105·4			
			105		
	20	106·2		M. 1·2 % of r.b.c. contain parasites	
			106	E. 3·6 ,, ,, ,,	
	21	105·6		M. 6·4 ,, ,, ,,	100 c.c. of sodium salicylate solution intravenously
			105·2	E. 6·8 ,, ,, ,,	
	22	105·4		M. 9·6 ,, ,, ,,	100 c.c. ,, ,,
			105	E. 13·2 ,, ,, ,,	
	23	104·2		M. 18·4 ,, ,, ,,	
			105·6	E. 21·6 ,, ,, ,,	
	24	104·4		M. 24·0 ,, ,, ,,	100 c.c. ,, ,,
			104	E. 20·0 ,, ,, ,,	
	25	106·2		M. 22·0 ,, ,, ,,	
			105·4	E. 28·4 ,, ,, ,,	
	26	105·2		M. 24·8 ,, ,, ,,	
			105·4	E. 28·4 ,, ,, ,,	
	27	104·8		M. 35·6 ,, ,, ,,	
			105	E. 36·4 ,, ,, ,,	
	28	105·6		M. 36·4 ,, ,, ,,	
			106·2	E. 38·4 ,, ,, ,,	
	29	105·6		M. 45·6 ,, ,, ,,	5 c.c. of salicylate of mercury solution intravenously
			106·2	E. 46·0 ,, ,, ,,	
9. xi.	30	—		Calf died at 8 a.m.	

EXPERIMENT II (*Calf* 18).

Treatment: *Tryposafrol*, 0·25 grammes rising to 3 grammes daily in 5 litres of sugared water on 17 successive days.

Date 1913	Day	Temp. °F. a.m.	p.m.	
16. iv.	1	102		30 infected *R. appendiculatus* nymphs were placed on the calf
			102·4	
	2	101·4		
			101·2	
	3	101·6		
			101·4	
	4	101·4		
			101·2	
	5	102		
			102·2	
	6	102·2		
			102·4	
	7	100·8		
			100·6	
	8	101·8		
			101·8	

EXPERIMENT II (*cont.*).

Date 1913	Day	Temp. °F.			
		a.m.	p.m.		*Treatment*
24. IV.	9	101·4	101·2		
	10	101·4	101·2		
	11	102·1	102·2		
	12	102·4	102·2		
	13	104·4	104·6	Fever begins	
	14	105·2	105·4		
	15	105	105·2		
	16	104·4	104·6		
	17	104·6	104·5		0·25 grammes tryposafrol in drink
	18	104·6	104·4		0·5 ,, ,, ,,
	19	104·2	104·4		1·0 ,, ,, ,,
	20	104·3	104·2		1·0 ,, ,, ,,
	21	105	105·2		1·0 ,, ,, ,,
	22	104	104·2		1·0 ,, ,, ,,
	23	104·4	104·4	Very few parasites found	1·0 ,, ,, ,,
	24	104	104·2	0·8 % of r.b.c. infected	1·0 ,, ,, ,,
	25	104·1	104	2·4 ,, ,,	1·0 ,, ,, ,,
	26	104·2	104·4	1·6 ,, ,,	1·0 ,, ,, ,,
	27	104	104·2	1·6 ,, ,,	1·0 ,, ,, ,,
	28	104·6	104·4	1·6 ,, ,,	1·5 ,, ,, ,,
	29	104·8	104·5	5·2 ,, ,,	2·0 ,, ,, ,,
	30	105·2	105·3	4·8 ,, ,,	2·0 ,, ,, ,,
	31	105·2	105·2	8·0 ,, ,,	3·0 ,, ,, ,,
	32	105	105·2	5·2 ,, ,,	3·0 ,, ,, ,,
18. V.	33	104	103·2	5·6 ,, ,, Calf died at 6 p.m.	3·0 ,, ,, ,,

EXPERIMENT III (*Calf* 19).

Treatment: *Tryposafrol*, 0·25 rising to 1·5 grammes daily in 5 litres of sugared water as a drink on 11 successive days.

Date 1913	Day	Temp. °F. a.m.	Temp. °F. p.m.		*Treatment*
14. v.	1	101·1	101·2	40 infected *R. appendiculatus* nymphs were placed on the calf	
	2	101·4	101·2		
	3	101·4	101·2		
	4	100·8	101		
	5	100·2	100·4		
	6	100·6	101		
	7	101·2	101·2		
	8	101·4	101·4		
	9	101·2	101·2		
	10	101·1	101·2		
	11	101·4	101·2		
	12	101·2	101·3		
	13	101·2	101·4		
	14	101·3	104·4	Fever begins	
	15	105	105·2		
	16	107	107·2		
	17	104	104·8		
	18	104·4	104·2	Very few parasites found	
	19	105	105·2	0·8 % of r.b.c. infected	0·25 grammes of tryposafrol in drink
	20	105·8	105·6	2·4 „ „	0·5 „ „ „ „
	21	105·6	105·8	6·0 „ „	1·0 „ „ „ „
	22	105·2	105·4	15·6 „ „	1·0 „ „ „ „
	23	105·6	105·5	16·8 „ „	1·5 „ „ „ „
	24	103·4	103·8	32·0 „ „	1·5 „ „ „ „
	25	102·1	102·4	34·0 „ „	1·5 „ „ „ „
	26	102·4	102·2	41·2 „ „	1·5 „ „ „ „
	27	104·4	104·6	51·2 „ „	1·5 „ „ „ „
	28	106·4	106·2	52·4 „ „	1·5 „ „ „ „
11. vi.	29	105·6	106·6	57·2 „ „ Calf died at 6.35 p.m.	1·5 „ „ „ „

EXPERIMENT IV (*Calf* 7).

Treatment: *Creosote and Oleum copaivae* (Creosote 0·2 c.c. + Ol. copaivae 3·7 c.c. diluted to form a 3 % solution).

Date 1912	Day	Temp. °F. a.m.	Temp. °F. p.m.		*Treatment*
29. II.	1	101·2	101·6	12 infected *R. appendiculatus* adults (6 ♂, 6 ♀) were placed on the calf	
	2	101·6	101·2		
	3	101·2	101·4		
	4	101·2	101		
	5	101·6	101·2		
	6	100·8	101·4		
	7	101	101·2		
	8	101·6	101·8		
	9	100·4	101		
	10	102	101·8		
	11	101	101·6		
	12	102·8	102·4		
	13	104·2	103·2	Fever begins	
	14	105·2	105·6		
	15	106	105·2		5 c.c. of drug injected intravenously
	16	105·4	106·2		5 c.c. ,, ,, ,,
	17	106·2	105·8		5 c.c. ,, ,, ,,
	18	106·2	105·6	Very few parasites found	5 c.c. ,, ,, ,,
	19	105·4	105·2	,, ,, ,,	—
	20	105	105·2	4·0 % of r.b.c. infected	5 c.c. ,, ,, ,,
	21	104·8	104·8	6·0 ,, ,,	5 c.c. ,, ,, ,,
	22	105	104·6	13·2 ,, ,,	5 c.c. ,, ,, ,,
	23	104·2	104·4	16·4 ,, ,,	
	24	104·6	104·8	20·4 ,, ,,	
	25	105	105·2	31·6 ,, ,,	
	26	105·8	106	39·6 ,, ,,	
	27	106·8	106·2	43·6 ,, ,,	
	28	106·4	105·6	49·2 ,, ,,	
	29	105	97·6	55·2 ,, ,,	
29. III.	30	—		Calf died at 5 p.m.	

EXPERIMENT V (*Calf* 6).

Treatment: *Arsacetin*, 5 % solution given on 7 alternate days in doses ranging from 2 to 5 c.c. intravenously.

Date 1912	Day	Temp. °F. a.m.	Temp. °F. p.m.		Treatment
9. VII.	1	101·4	101·8	18 infected *R. appendiculatus* adults (9 ♂, 9 ♀) were placed on the calf	
	2	101·6	101·2		
	3	101	101·4		
	4	101·2	101·4		
	5	101·8	101·6		
	6	101·2	101·6		
	7	101·8	101·2		
	8	100·6	101		
	9	100·8	101·4		
	10	101·2	101·8		
	11	102·4	102·2		
	12	103·4	104	Fever begins	
	13	104·6	105·2		
	14	104·2	104·4		
	15	104·6	104·6	Very few parasites found	
	16	104·8	105	0·4 % of r.b.c. infected	2 c.c. of 5 % arsacetin solution intravenously
	17	105·4	106	0·8 ,, ,,	
	18	106	106·2	2·0 ,, ,,	2 c.c. ,, ,, ,,
	19	106	105·4	6·8 ,, ,,	
	20	105	105	13·2 ,, ,,	4 c.c. ,, ,, ,,
	21	104·8	104·6	19·2 ,, ,,	
	22	104·8	105	—	5 c.c. ,, ,, ,,
	23	105·2	105	24·4 ,, ,,	
	24	105·2	105	30·0 ,, ,,	5 c.c. ,, ,, ,,
	25	105·8	106	31·2 ,, ,,	
	26	106·4	106·6	41·2 ,, ,,	5 c.c. ,, ,, ,,
	27	106·6	106	41·6 ,, ,,	
	28	105·2	104·8	—	5 c.c. ,, ,, ,,
6. VIII.	29	104		Calf died at 6 p.m.	

EXPERIMENT VI (*Calf* 3).

Treatment: *Soamin*, 2·5 grammes dissolved in 12·5 c.c. of hot water and injected intramuscularly, whilst warm, on 7 days.

Date 1911	Day	Temp. °F.			Treatment
		a.m.	p.m.		
3. VII.	1	100·6		7 infected *R. appendiculatus* adults (1 ♂, 6 ♀) were placed on the calf	
			101·8		
	2	99·6			
			101		
	3	101			
			102		
	4	101·4			
			101·8		
	5	100·8			
			103		
	6	101			
			102·4		
	7	101			
			102·6		
	8	100·4			
			102·6		
	9	101·4			
			101·8		
	10	102·4			
			102·2		
	11	101			
			101·6		
	12	102·4			
			103·8	Fever begins	
	13	102·6			
			105·4		
	14	105·4			
			105		
	15	105·6			
			104·8		
	16	105·2			
			105		
	17	105·4			
			105·4		
	18	105·2			
			105·6		
	19	106			
			105·8	E. Very few parasites found	2·5 grammes of soamin, intramuscularly
	20	105·6		M. ,, ,, ,,	
			105·6	E. ,, ,, ,,	
	21	105·8		M. 0·8 % of r.b.c. infected	2·5 ,, ,,
			106·2	E. 15·2 ,, ,,	
	22	104·8		M. 25·6 ,, ,,	2·5 ,, ,,
			105·6	E. 34·0 ,, ,,	
	23	105		M. 39·2 ,, ,,	2·5 ,, ,,
			104·6	E. —	
	24	104·6		M. 46·4 ,, ,,	
			105·2	E. 54·4 ,, ,,	
	25	105		M. 60·8 ,, ,,	2·5 ,, ,,
			105·6	E. 61·6 ,, ,,	
	26	104·8		M. 66·8 ,, ,,	
			105·4	E. 68·4 ,, ,,	
	27	105		M. 66·0 ,, ,,	2·5 ,, ,,
			104·8	E. 75·0 ,, ,,	
	28	103·8		M. 75·0 ,, ,,	2·5 ,, ,,
			106	E. 75·6 ,, ,,	
	29	106			
			105·2		
	30	105·4		M. 75·8 ,, ,,	
			101		
2. VIII.	31	102		Calf died at 3 p.m.	

EXPERIMENT VII (*Calf* 11).

Treatment: *Soamin*, 2 % solution given intravenously in doses ranging from 3 to 13 c.c., following on the intravenous injection of 2 to 4 c.c. of a solution of eosin and sodium bicarbonate ($\frac{1}{2}$ a grain of each per c.c.).

Date 1912	Day	Temp. ° F. a.m.	Temp. ° F. p.m.		Treatment: 2 % soamin. Dose	Treatment: Eosin + sod. bicarb. solution. Dose
7. x.	1	101·2	101·6	30 infected *R. appendiculatus* nymphs were placed on the calf		
	2	101·8	101·2			
	3	101·6	101·8			
	4	102	101·6			
	5	101·4	101·8			
	6	101·6	101·8			
	7	102·8	102·2			
	8	102	101·4			
	9	100·8	100·8			
	10	100·4	—			
	11	101·2	103·8			
	12	101·8	102·6			
	13	101·6	101·6			
	14	101·8	103·2			
	15	104·4	105·4	Fever begins		
	16	105·4	106			
	17	105·2	106·2			
	18	106·8	106·6			
	19	107	107·2	Very few parasites found		
	20	105·8	106·8	,, ,, ,,		
	21	104·6	104·8	,, ,, ,,		
	22	104	105	3·6 % of r.b.c. infected		
	23	104	104·6	14·4 ,, ,,	3 c.c.	2 c.c.
	24	104·8	106·2	20·4 ,, ,,	3 c.c.	2 c.c.
	25	105	105·2	25·6 ,, ,,	10 c.c.	2 c.c.
	26	105·8	106	39·6 ,, ,,	13 c.c.	3 c.c.
	27	106·4	106·2	42·8 ,, ,,	10 c.c.	3 c.c.
	28	106·4	100·2	43·6 ,, ,,	8 c.c.	4 c.c.
4. xi.	29	—		Calf died at 5.30 a.m.		

EXPERIMENT VIII (*Cow* 4).

Treatment: "606," 2 grammes given intravenously in one dose. Weight of cow 1008 lbs.

Date 1911	Day	Temp. °F. a.m.	Temp. °F. p.m.		
18. II.	1	—	100·6	12 infected *R. appendiculatus* (6 ♂, 6 ♀) were placed upon the cow	
	2	100·8	100·6		
	3	100·6	100·8		
	4	101	101·2		
	5	100·8	101		
	6	101·2	100·6		
	7	101·4	101		
	8	100·8	100·4		
	9	100·6	101		
	10	101	101·2		
	11	101·8	101·6		
	12	101·4	101·6		
	13	104	103·6	Fever begins	
	14	102	103·6		
	15	104	103·8		
	16	101·6	101·8		
	17	103·4	103·2		
	18	103·4	104·6		
	19	105·2	105		
	20	105·4	105·2	M. 0·4 % of r.b.c. contain parasites E. 0·8 ,, ,, ,,	
	21	104·4	104·2	M. 6·0 ,, ,, ,, E. 4·0 ,, ,, ,,	
	22	103·6	104·4	at 10 a.m. 6·4 % of r.b.c. contain parasites 3 p.m. 8·4 ,, ,, ,, 5 ,, 8·4 ,, ,, ,, 7 ,, 8·8 ,, ,, ,, 9 ,, 13·2 ,, ,, ,,	 at time when *treated* with "606" intravenously 2 hrs later 4 ,, 6 ,,
	23	101·4	98·2	11 a.m. 21·0 ,, ,, ,,	
13. III.	24	—		Cow found dead at 6 a.m.	

EXPERIMENT IX (*Calf* 15).

Treatment: *Emetine hydrochloride*, 1 % in NaCl solution given intravenously in doses ranging from 1 to 10 c.c. on 9 successive days.

Date 1913	Day	Temp. ° F. a.m.	Temp. ° F. p.m.		*Treatment*
14. I.	1	102	101·4	26 infected *R. appendiculatus* adults (19 ♂, 7 ♀) were placed on the calf	
	2	102	101·4		
	3	101·2	101·2		
	4	101·6	101·4		
	5	101·2	101·2		
	6	101	101		
	7	101·4	101·4		
	8	101·2	101·2		
	9	101·2	101·4		
	10	101·2	101·4		
	11	101	101·2		
	12	101·2	101·4		
	13	101·4	101·6		
	14	105·4	105·2	Fever begins	
	15	105	105·4		
	16	107·4	107·2		
	17	106·2	106·8		
	18	106·4	106·6	0·8 % of r.b.c. contain parasites	
	19	107·2	107·4	13·2 ,, ,, ,, ,,	1 c.c. of drug intravenously
	20	106	106·4	22·4 ,, ,, ,, ,,	2 c.c. ,, ,, ,,
	21	106	106·4	24·0 ,, ,, ,, ,,	4 c.c. ,, ,, ,,
	22	105	105·4	44·8 ,, ,, ,, ,,	5 c.c. ,, ,, ,,
	23	105	105	65·2 ,, ,, ,, ,,	8 c.c. ,, ,, ,,
	24	105	105	73·6 ,, ,, ,, ,,	10 c.c. ,, ,, ,,
	25	105	105	76·4 ,, ,, ,, ,,	4 c.c. ,, ,, ,,
	26	105	104·8	78·8 ,, ,, ,, ,,	5 c.c. ,, ,, ,,
	27	106·1	106·2	78·8 ,, ,, ,, ,,	5 c.c. ,, ,, ,,
	28	107	107	84·2 ,, ,, ,, ,,	
11. II.	29	101·6		Calf killed when moribund at 8.30 a.m.	

EXPERIMENT X (*Calf* 9).

Treatment: *Mercury salicylate*, 1 % in 0·8 % NaCl solution given intravenously on 9 days in doses ranging from 4 to 20 c.c.

Date 1911	Day	Temp. °F. a.m.	p.m.		Treatment
8. XI.	1	—		14 infected *R. appendiculatus* nymphs were placed on the calf	
			103		
	2	102·4		8 infected *R. appendiculatus* adults (4 ♂, 4 ♀) were placed on the calf	
			102·6		
	3	103			
			102·2		
	4	101·4			
			101·6		
	5	101·6			
			101·2		
	6	101·4			
			101·6		
	7	101·6			
			101·2		
	8	101·2			
			101·2		
	9	101·4			
			101·6		
	10	101·6			
			101·8		
	11	102·4			
			101·8		
	12	104·4		Fever begins	
			104·6		
	13	105		Koch's "blue bodies" found in gland smear	
			104·4		
	14	104·4			4 c.c. of 1 % salicylate of mercury intravenously
			104·6		
	15	104			6 c.c. ,, ,, ,,
			104·2		
	16	105		M. Very few parasites found	10 c.c. ,, ,, ,,
			106·6	E. ,, ,, ,, ,,	
	17	106		M. ,, ,, ,, ,,	5 c.c. ,, ,, ,,
			105·2	E. ,, ,, ,, ,,	
	18	105·8		M. ,, ,, ,, ,,	5 c.c. ,, ,, ,,
			106·4	E. ,, ,, ,, ,,	
	19	104·2		M. 6·0 % of r.b.c. infected	10 c.c. ,, ,, ,,
			104·4	E. 6·2 ,, ,, ,,	
	20	104·6		M. 8·4 ,, ,, ,,	—
			104·2	E. 10·0 ,, ,, ,,	
	21	104·6		M. 14·8 ,, ,, ,,	20 c.c. ,, ,, ,,
			104·6	E. 13·8 ,, ,, ,,	
	22	104·6		M. 13·2 ,, ,, ,,	12 c.c. ,, ,, ,,
			104·2	E. 17·2 ,, ,, ,,	
	23	105·8		M. 19·2 ,, ,, ,,	12 c.c. ,, ,, ,,
			105·4	E. 21·2 ,, ,, ,,	
	24	105·2		M. 28·0 ,, ,, ,,	
			106·6	E. 23·2 ,, ,, ,,	
	25	106·4		M. 30·4 ,, ,, ,,	
			105·8	E. 31·2 ,, ,, ,,	
	26	103·2		M. 32·0 ,, ,, ,,	
			103·6	E. 37·6 ,, ,, ,,	
4. XII.	27	97		M. 39·2 ,, ,, ,,	
				Calf killed when moribund at 2.30 p.m.	

Experiment XI (*Calf* 10).

Treatment: *Mercury succinimide* in 3 % solution given intravenously, 2, 4 and 3 c.c. being injected on the 15th, 16th and 19th days respectively.

Date 1912	Day	Temp. ° F. a.m.	p.m.		*Treatment*
30. I.	1	—	101·2	12 infected *R. appendiculatus* nymphs were placed on the calf	
	2	101·4	101·4		
	3	101·6	101		
	4	101·2	101·4		
	5	101	101·2		
	6	101·4	101		
	7	101·2	102		
	8	101·6	101·4		
	9	101·8	101·2		
	10	101·4	101·8		
	11	103	103·2	Fever begins	
	12	103·2	103·8		
	13	104·6	104·6		
	14	104·8	104·4		
	15	104·8	105	Very few parasites found	2 c.c. of drug given intravenously
	16	105·2	105·4	,, ,, ,,	4 c.c. ,, ,, ,,
	17	104·4	104·8	0·4 % of r.b.c. infected	
	18	102·6	103·4	1·6 ,, ,,	
	19	102·6	103·2	5·2 ,, ,,	3 c.c. ,,
	20	100·6	100·8	8·4 ,, ,,	
	21	100·6	100·6	14·8 ,, ,,	
	22	100·2	100·2	11·6 ,, ,,	
	23	99·6	99·8	20·8 ,, ,,	
	24	99·4	99·4	15·6 ,, ,,	
	25	99·4	99·2	19·2 ,, ,,	
	26	99·4	99·2	24·0 ,, ,,	
	27	98·6	97·8	23·4 ,, ,,	
26. II.	28	—		Calf found dead	

EXPERIMENT XII (*Calf* 5).

Treatment: *Quinine bihydrochloride*, 55–60 grains dissolved in 25 c.c. of water, injected subcutaneously at 11 a.m. on 14 successive days. (Prepared as 5 grain tabloids.)

Date 1911	Day	Temp. °F. mean M. & E.	
25. IV.	1	101·2	12 infected *R. appendiculatus* adults (6 ♂, 6 ♀) were placed on the calf
	2	101·4	*Note*: it is not clear which lot of ticks produced infection,
	3	101	possibly it may have been one of those following
	4	101·5	16 infected *R. appendiculatus* nymphs were placed on the calf
	5	101·2	
	6	101·8	
	7	102·3	some ,, ,, ,, ,, ,, ,, ,,
	8	101·8	
	9	101·2	
	10	101·3	some ,, ,, ,, ,, ,, ,, ,,
	11	100·6	
	12	101	some ,, ,, ,, ,, ,, ,, ,,
	13	101·5	
	14	101·6	
	15	101	
	16	102	
	17	102·1	
	18	102	
	19	101·5	
	20	102·1	
	21	101	
	22	100·6	
	23	101·5	
	24	102·1	
	25	101·3	
	26	101·2	
	27	101·4	

	Temp. °F. a.m.	p.m.	
28	103	104·4	Transitory febrile rise
29	104·6	101·8	
30	101·4	102·2	
31	100·2	102·2	
32	100·6	101·6	
33	100·6	101·4	
34	101·8	101·6	
35	100·8	101·4	
36	100·1	—	
37	101	—	
38	101	—	
39	101·6	—	

Experiment XII (*cont.*).

Date 1911	Day	Temp. ° F.				Treatment
		a.m.	p.m.			
3. vi.	40	104		Fever begins		
			105·2			
	41	105·8		Very few parasites found		
			106·2			
	42	104·8		,, ,, ,, ,,		
			106·8			
	43	105·2		M.	0·8 % of r.b.c. infected	60 grains quinine bihydrochloride
			105·2	E.	0·8 ,, ,,	
	44	105·6		M.	0·8 ,, ,,	60 ,, ,, ,,
			105·8	E.	1·2 ,, ,,	
	45	104·8		M.	0·4 ,, ,,	60 ,, ,, ,,
			104·8	E.	3·2 ,, ,,	
	46	105·6		M.	3·2 ,, ,,	60 ,, ,, ,,
			105	E.	3·2 ,, ,,	
	47	104·8		M.	4·4 ,, ,,	60 ,, ,, ,,
			103·2	E.	6·0 ,, ,,	
	48	104·2		M.	8·8 ,, ,,	60 ,, ,, ,,
			103·4	E.	4·8 ,, ,,	
	49	102		M.	3·2 ,, ,,	60 ,, ,, ,,
			101·8	E.	9·2 ,, ,,	
	50	100		M.	13·2 ,, ,,	55 ,, ,, ,,
			102	E.	11·6 ,, ,,	
	51	102·6		M.	15·6 ,, ,,	60 ,, ,, ,,
			102·6	E.	18·0 ,, ,,	
	52	101		M.	16·0 ,, ,,	60 ,, ,, ,,
			104·2	E.	—	
	53	102		M.	24·0 ,, ,,	60 ,, ,, ,,
			103·8	E.	25·2 ,, ,,	
	54	103		M.	24·0 ,, ,,	60 ,, ,, ,,
			105	E.	21·6 ,, ,,	
	55	103·6		M.	29·6 ,, ,,	60 ,, ,, ,,
			105·2	E.	33·2 ,, ,,	
19. vi.	56	102·6		M.	31·2 ,, ,,	60 ,, ,, ,,
			101·8	Calf killed when moribund at 6.15 p.m.		

EXPERIMENT XIII (*Calf* 4).

Treatment: *Quinine hydrochloride*, 30–45 grains in 20 c.c. of water injected intramuscularly at 10.45 a.m. on 5 days (5 grain tabloids) and *Quinine bihydrochloride*, ditto on 7 days.

Date 1911	Day	Temp. °F. a.m.	p.m.		*Treatment*
29. v.	1	—		9 infected *R. appendiculatus* nymphs were placed on the calf	
	2	100·6			
	3	101·2			
	4	100·2			
	5	101·2			
			101·8		
	6	101			
			103		
	7	101·4			
			102·4		
	8	101·6			
			102		
	9	101			
			102·4		
	10	100·6			
			103		
	11	102·6			
			102·8		
	12	102·6			
			104·4	Fever begins	
	13	104·8			
			104·2		
	14	105·6			
			106·4		
	15	104·6			
			106·4		
	16	104·2			
			104		
	17	106·2		0·1 % of r.b.c. contain parasites	30 grains quinine hydrochloride, intramusc.
			106·2	0·4 ,, ,, ,, ,,	
	18	104·8		1·6 ,, ,, ,, ,,	45 ,, ,, ,,
			106·4	0·8 ,, ,, ,, ,,	
	19	105		4·8 ,, ,, ,, ,,	45 ,, ,, ,,
			105	7·2 ,, ,, ,, ,,	
	20	106·4		9·6 ,, ,, ,, ,,	45 ,, ,, ,,
			105·4	9·2 ,, ,, ,, ,,	
	21	104·4		25·2 ,, ,, ,, ,,	45 ,, ,, ,,
			105	—	
	22	104·6		23·2 ,, ,, ,, ,,	45 grains quinine bihydrochloride, intramusc.
			104·2	—	
	23	104·4		30·4 ,, ,, ,, ,,	45 ,, ,, ,,
			105	36·4 ,, ,, ,, ,,	
	24	103·8		45·6 ,, ,, ,, ,,	45 ,, ,, ,,
			104·2	36·8 ,, ,, ,, ,,	
	25	103·4		38·8 ,, ,, ,, ,,	—
			104·6	42·0 ,, ,, ,, ,,	
	26	105		44·0 ,, ,, ,, ,,	—
			105·8	51·2 ,, ,, ,, ,,	
	27	106·2		48·4 ,, ,, ,, ,,	45 ,, ,, ,,
			106	48·8 ,, ,, ,, ,,	
	28	106·2		49·6 ,, ,, ,, ,,	45 ,, ,, ,,
			106	52·4 ,, ,, ,, ,,	
	29	105·8		56·0 ,, ,, ,, ,,	45 ,, ,, ,,
			105·7	54·8 ,, ,, ,, ,,	
27. vi.	30	104		58·4 ,, ,, ,, ,,	45 ,, ,, ,,
			99·2	59·2 ,, ,, ,, ,,	
				Calf died during the night	

EXPERIMENT XIV (*Calf* 22).

Treatment: *Ethylhydrocupreine HCl*, subcutaneous injection of 24 c.c. of an 8 % solution on each of five successive days, beginning on the second day after the appearance of parasites in the calf's blood.

Date 1911	Day	Temp. °F. a.m.	p.m.		Treatment
22. XII.	1	102	103·4	50 infected *R. appendiculatus* nymphs were placed on the calf	
	2	101	102·8		
	3	101·4	102·8		
	4	101·6	102·6		
	5	102·4	102		
	6	101·6	102		
	7	101·4	102·2		
	8	101·2	103		
	9	101·8	102·4		
	10	102·6	102		
	11	101·8	103·6	Fever begins	
	12	101·6	103·6		
	13	103·4	104		
	14	102·8	106·2		
	15	105·3	104·8		
	16	104·8	105		
	17	104	105·2		
	18	105	105·4		
	19	106	105·8	Very few parasites found	
	20	105	104·2	2 % of r.b.c. infected	24 c.c. of drug subcutaneously
	21	104·2	102·5	7·2 ,, ,,	24 c.c. ,, ,, ,,
	22	102·2	102·2	8·8 ,, ,,	24 c.c. ,, ,, ,,
	23	101·6	103·2	20·8 ,, ,,	24 c.c. ,, ,, ,,
	24	102·6	103·2	22·0 ,, ,,	24 c.c. ,, ,, ,,
	25	103·4	104·6	—	
16. I. 1912	26	104·6		36·0 ,, ,, Calf killed at 12.20 p.m.	

Experiment XV (*Calf* 16).

Treatment: *Ammonium fluoride*, 0·5 % in 0·8 % NaCl solution injected in doses of 18–20 c.c. intravenously on 9 successive days.

Date 1913	Day	Temp. °F. a.m.	Temp. °F. p.m.		Treatment
4. III.	1	—	102·2	50 infected *R. appendiculatus* nymphs were placed on the calf	
	2	102·2	102·4		
	3	102·2	102·6		
	4	101·8	104·6		
	5	102·2	102·4		
	6	102·4	102·6		
	7	102·4	102·4		
	8	102·4	102·2		
	9	102·6	102·4		
	10	102·2	102·4		
	11	103	102·6		
	12	103·6	103·4	Fever begins	
	13	103·4	103·6		
	14	105	105·2		
	15	106·2	106·6		
	16	105·8	105·2	A few parasites found	
	17	107·4	107·4		20 c.c. of ammonium fluoride sol. intrav.
	18	104·4	104·2		20 c.c. ,, ,, ,, ,,
	19	105	105·2		20 c.c. ,, ,, ,, ,,
	20	105·4	105·8		20 c.c. ,, ,, ,, ,,
	21	104·8	104·6		20 c.c. ,, ,, ,, ,,
	22	104·8	104·6		18 c.c. ,, ,, ,, ,,
	23	105·2	105·4		20 c.c. ,, ,, ,, ,,
	24	106·4	106·2		20 c.c. ,, ,, ,, ,,
	25	107	107	46·8 % of r.b.c. infect.	20 c.c. ,, ,, ,, ,,
	26	107·4	107·2	43·6 ,, ,,	
	27	107	107	47·2 ,, ,,	
31. III.	28	—		Calf died	

Experiment XVI (*Calf* 20).

Treatment: *Potassium iodide* in 25 % solution, injected intravenously on 5 successive days, the dose rising from 20 to 40 c.c.

Date 1913	Day	Temp. °F.			Treatment
		a.m.	p.m.		
10. viii.	1	101·4	101·4	24 infected *R. appendiculatus* nymphs (removed when partly gorged from calf 21 on 10. viii. 1913) were placed on the calf	
	2	102·2	101·6		
	3	102	101·6		
	4	101	101·4		
	5	101·6	101·1		
	6	101·4	101·8		
	7	101·6	101·6		
	8	102	102		
	9	101·4	102·2		
	10	104·1	104·2	Fever begins	
	11	104·4	104·6		
	12	105	105		
	13	105·4	105·4		
	14	105·3	105·2		
	15	105·4	105·2		
	16	107	106·8		20 c.c. of drug intravenously
	17	106·2	106·4	Very few parasites found	20 c.c. ,, ,,
	18	105·8	106·8	2·0 % of r.b.c. infected	40 c.c. ,, ,,
	19	105·8	106·4	7·6 ,, ,, ,,	40 c.c. ,, ,,
	20	105·4	106·2	12·4 ,, ,, ,,	40 c.c. ,, ,,
	21	104·8	105·4	—	
31. viii.	22	104·6		16·8 ,, ,, ,, Calf died at 11 a.m.	

Experiment XVII (*Calf* 21).

Treatment: *Calcium lactate*, in 10 % solution, was injected intravenously on 7 successive days, the dose rising from 3 to 5 c.c.

Date 1913	Day	Temp. °F a.m.	Temp. °F p.m.		Treatment
31. x.	1	101·6	102·6	50 infected *R. appendiculatus* nymphs were placed on the calf	
	2	102·2	102·8		
	3	102	102·8		
	4	101·8	102·4		
	5	102·6	102·6		
	6	102·4	102·6		
	7	102·6	102·8		
	8	102	102·2		
	9	102·4	102·6		
	10	102·2	102·8		
	11	103·2	103·4		
	12	102·6	104·4	Fever begins	
	13	105·2	106		
	14	105·1	106·2		
	15	105·6	106·6		
	16	106·8	106·9		
	17	106·4	106·8		
	18	105·6	106·2	Very few parasites found	
	19	105·4	102·8	6·8 % of r.b.c. infected	3 c.c. of drug intravenously
	20	103·2	102	14·0 ,, ,,	5 c.c. ,, ,,
	21	105	103	26·8 ,, ,,	5 c.c. ,, ,,
	22	104·8	103	37·2 ,, ,,	5 c.c. ,, ,,
	23	104·6	103·2	54·4 ,, ,,	5 c.c. ,, ,,
	24	106·2	104·2	55·2 ,, ,,	5 c.c. ,, ,,
24. xi.	25	105·2		56·0 ,, ,, Calf died at 3.30 p.m.	5 c.c. ,, ,,

EXPERIMENT XVIII (*Calf* 17).

Treatment: *Nuclein* from thymus gland, 10 c.c. of a 5 % solution given subcutaneously on 5 days.

Date 1913	Day	Temp. °F. a.m.	p.m.		*Treatment*
7. III.	1	—	102·4	ca. 140 infected *R. appendiculatus* nymphs were placed on the calf	
	2	101·8	101·6		
	3	101·4	101·2		
	4	102	101·4		
	5	102·2	102		
	6	102	102·2		
	7	102	102·2		
	8	102	102·4		
	9	102	102·2		
	10	102	102·4		
	11	104·6	104·4	Fever begins	
	12	105·5	105·4		
	13	105·2	105·6		10 c.c. of nuclein solution subcutaneously
	14	105·4	105·2		
	15	106·6	106·8	Very few parasites found	
	16	106	106·4	,, ,, ,,	10 c.c. ,, ,, ,,
	17	106·2	106	2·4 % of r.b.c. infected	
	18	104·4	104·2	6·8 ,, ,, ,,	
	19	104	104·4	16·0 ,, ,, ,,	10 c.c. ,, ,, ,,
	20	104·2	104·6		
	21	105	105·4		
	22	105·4	105·2		
	23	106	106·4		10 c.c. ,, ,, ,,
	24	106·4	106·2	44·4 ,, ,, ,,	
	25	106·8	106·6	44·8 ,, ,, ,,	10 c.c. ,, ,, ,,
	26	106·2	106·4	50·0 ,, ,, ,,	
2. IV.	27	105·4	105·8	58·8 ,, ,, ,, Calf died 28th day	

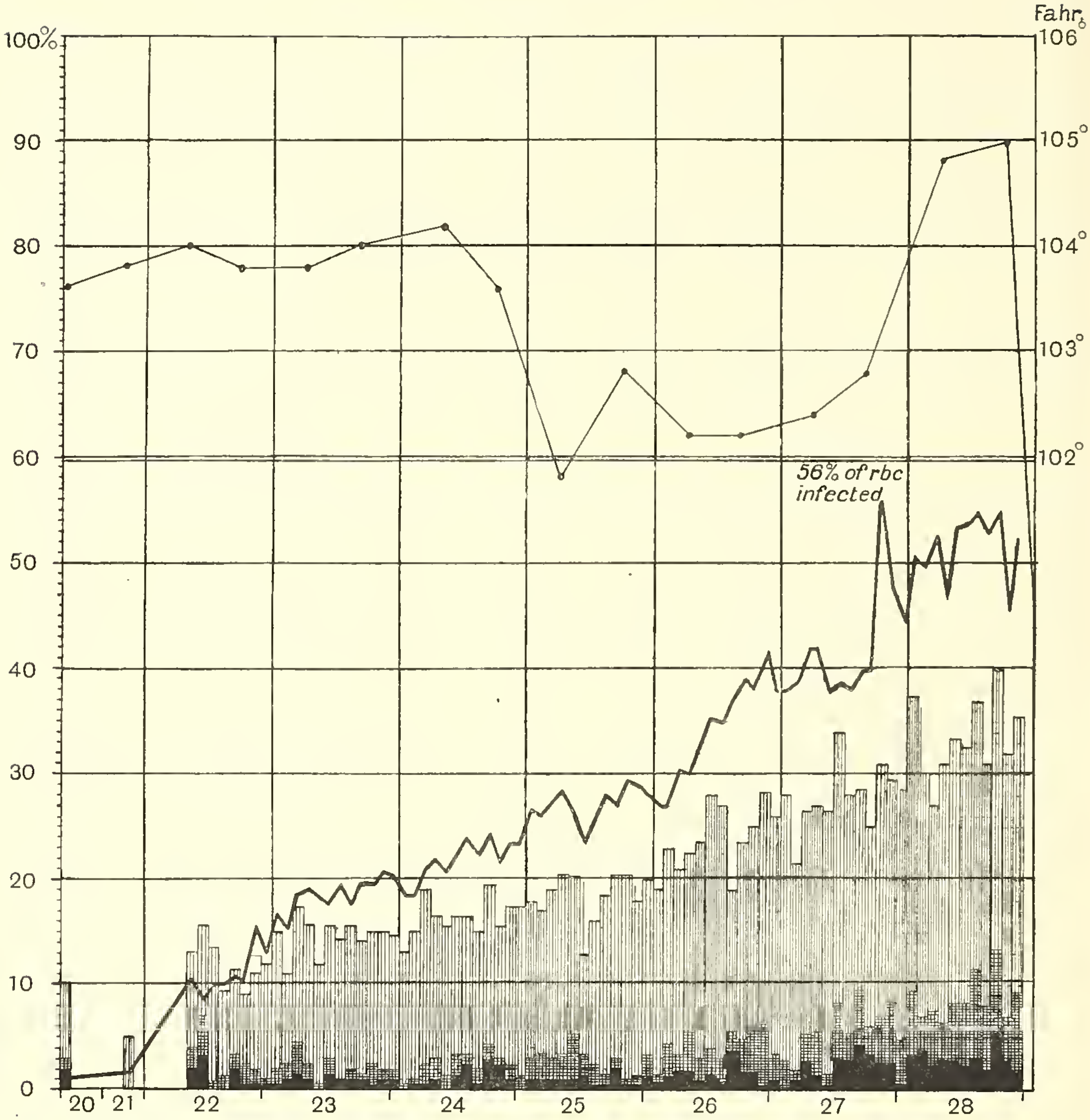


CHART RELATING TO CONTROL I (*Cow* 1).

The body temperature is indicated by the thin line above. The increase in the percentage of infected red blood corpuscles is represented by the bold black line rising from 1·2 % on the 20th day after tick infestation to 56 % on the 27th day. The vertical columns represent the total number of infected corpuscles taken as 100 (corresponding to the percentage column on the left); the white part above each column represents the proportion of corpuscles containing a single parasite, the vertically, horizontally shaded, and black parts indicate respectively the proportion of corpuscles containing 2, 3 and 4 or more parasites. The days of observation are recorded below. The blood films were prepared every two hours, day and night, starting on day 22.

Records of Cattle which were not treated.

For the sake of comparison I append the protocols relating to three animals which were not subjected to treatment and which may be regarded as controls. In the case of Control I a very careful examination of the blood was made in respect to parasites, the results being given graphically in the accompanying chart.

CONTROL I (*Cow* 1).

Date	Day	Temp. ° F.		Untreated.
		a.m.	p.m.	
10. x. 1910	1	102·2	102	13 infected *R. appendiculatus* (6 ♂, 7 ♀) were placed on the cow at 4.30 p.m.
	2	101·6	101·8	
	3	102·2	101·6	
	4	101·8	—	
	5	102·2	101·8	
	6	102·2	102	
	7	101·8	99·8	
	8	101·6	100·2	
	9	101·4	101	
	10	100·2	99·2	
	11	99·4	100·2	
	12	102	102·4	
	13	100·6	98·6	
	14	103·6	102·6	Fever begins
	15	104·4	103·8	
	16	105	104·6	
	17	103·8	104·4	
	18	104·2	103·6	
	19	104·6	104·4	Two r.b.c. in a blood-film are found to contain parasites

CONTROL I (*cont.*).

Date 1910	Day	Temp. °F. a.m.	Temp. °F. p.m.	Time	% of r.b.c. infected	% of r.b.c. containing					Free forms found per 1000 r.b.c.	Remarks
						1	2	3	4	5 or more parasites		
29. x.	20	103·6	103·8	11 a.m.	1·2	90*	7	1	1	1	—	
	21	103·6	103·8	11 ,,	1·6	95*	5	—	—	—	—	
	22	104		11 ,,	10·8	87	9	2	2	—	—	
			103·8	1 p.m.	8·4	84	8·5	4	0·5	3	—	
				3 ,,	10	86·5	12·5	1	—	—	—	
				5 ,,	10	90·5	8	1·5	—	—	—	
				7 ,,	10·8	88·5	8	1·5	1	1	—	
				9 ,,	10·4	91	6·5	2	0·5	—	—	
				11 ,,	15·5	89	9	1·5	0·5	—	—	
	23	103·8	104	1 a.m.	12·8	88	11	0·5	0·5	—	—	Cow not feeding
				3 ,,	16·8	85	13	1·5	—	0·5	—	
				5 ,,	15·2	89	8·5	1·5	0·5	0·5	—	
				7 ,,	18·8	83	12·5	3	1·5	—	—	
				9 ,,	19·2	84·5	13	1·5	—	1	—	
				11 ,,	18	88	11·5	0·5	—	—	—	
				1 p.m.	17·6	85	12	1·5	0·5	1	—	
				3 ,,	19·6	86	13	—	1	—	—	
				5 ,,	17·6	84	14	0·8	0·4	0·8	—	
				7 ,,	19·6	86	12·5	0·5	1	—	—	
				9 ,,	19·6	85	12·5	2	0·5	—	—	
				11 ,,	20·8	85	13	1	1	—	—	
	24	104·2	103·6	1 a.m.	20·4	85	13	1	1	—	—	Cow not feeding
				3 ,,	18·4	87	12·5	—	—	0·5	—	
				5 ,,	18·4	85	14	0·5	0·5	—	—	
				7 ,,	21·2	81	16·5	2	—	0·5	—	
				9 ,,	22	84	13	2	1	—	—	
				11 ,,	20·8	85	14	1·0	—	—	—	
				1 p.m.	22·4	84	12·5	2	1	0·5	—	
				3 ,,	24	84	12·5	1	2	0·5	—	
				5 ,,	22·4	84	13	1·5	0·5	—	—	
				7 ,,	24·4	81	14·5	1·5	0·5	—	—	
				9 ,,	21·6	85	12	0·5	2	0·5	—	
				11 ,,	23·2	83	14·5	1·5	1	—	—	
	25	100·8	102·8	1 a.m.	23·2	83	15·5	1·5	—	—	0	Cow not feeding
				3 ,,	26·8	82	15	2	1	—	0	
				5 ,,	26	83	13·5	2·5	0·5	0·5	0	
				7 ,,	27·2	81	16	2	1	—	1	
				9 ,,	28·4	80	16·5	2·5	1	—	0	
				11 ,,	26	80	15	4	1	—	0	
				1 p.m.	23·2	87	9·5	2	0·5	1	0	
				3 ,,	25·2	84	13·5	2	—	0·5	0	
				5 ,,	28	82	16·5	1	0·5	—	0	
				7 ,,	27	80	16	1	2	1	0	
				9 ,,	29·3	79	20	0·5	0·5	—	0	
				11 ,,	29	82	16·5	1	0·5	—	0	

* 100 infected r.b.c. counted for types, 200 in the rest.

CONTROL I (*cont.*).

Date 1910	Day	Temp. °F. a.m.	Temp. °F. p.m.	Time	% of r.b.c. infected	% of r.b.c. containing 1	2	3	4	5 or more parasites	Free forms found per 1000 r.b.c.	Remarks
4. XI.	26	102·2	102·2	1 a.m.	28	80	16·5	2	1·5	—	2	Cow weak
				3 ,,	27	81	17·5	1	0·5	—	0	
				5 ,,	27	77	18·5	3	1	0·5	0	
				7 ,,	30·4	79	17·5	1·5	1	1	0	
				9 ,,	30	78	16	4	1·5	0·5	4	
				11 ,,	33	76	21	2	0·5	0·5	2	
				1 p.m.	35·2	73	23	2·5	1	0·5	8	
				3 ,,	35	73	24	2	1	—	6	
				5 ,,	38·4	81	13·5	1·5	2·5	1·5	8	
				7 ,,	39·2	77	18	3·5	1·5	—	8·5*	
				9 ,,	38	75	19	4·5	1·5	—	32	
				11 ,,	41·6	72	21·5	6	0·5	—	5	
	27	102·4	102·8	1 a.m.	38	74	22·5	2·5	1	—	—	
				3 ,,	38	72	26	2	0	0	12	
				5 ,,	38·8	79	19	1	1	0	2	
				7 ,,	42	74	20·5	2·5	2·5	0·5	3	
				9 ,,	42	73	21·5	4	0	1·5	5	
				11 ,,	38	74	24·5	1	0·5	0	77†	
				1 p.m.	38·8	66	25·6	5·2	2	1·2	8	
				3 ,,	38‡	72	22·5	2·5	2·5	0·5	6	
				5 ,,	40	72	18	5·5	3	1·5	8	
				7 ,,	40	75	19	2·5	1·5	2	2	
				9 ,,	56‡	69	24	4·5	1·5	1	7	
				11 ,,	47·6	71	20·5	6	1	1·5	3	
	28	104·8	105	1 a.m.	44·4	72	23	4·5	0	0·5	1	
				3 ,,	50·8	63	27·5	6	3	0·5	1	
				5 ,,	49·6	70	23	3	3	1	18	
				7 ,,	52·8	73	19·5	5	1·5	1	3	
				9 ,,	46·4	69	24·5	3·5	1	2	33	
				11 ,,	54‡	77	24·5	5·5	3	0	11	
				1 p.m.	54	68	23·5	6	1·5	1	2	
				3 ,,	54·8	63	25·5	8·5	2	1	1	
				5 ,,	52·8	69	23	6	1	1	9	
				7 ,,	54·8	60	26·5	8	4·5	1	5	
				9 ,,	45·4‡	68	25	4	2·5	0·5	6	
				11 ,,	52·4	65	25·5	7·5	2	0	13	
7. XI.	29	—		1 a.m.	Cow found dead							

* 2000 r.b.c. counted.

† Film very unequal, 2000 r.b.c. counted.

‡ 500 r.b.c. counted for % of infection, 250 counted otherwise.

Control II (*Cow* 2).

Untreated.

Date	Day	Temp. F. a.m.	p.m.	
22. xi. 1910	1	—		19 infected *R. appendiculatus* (10 ♂, 9 ♀) were placed on the cow at 9 p.m.
	2	100·6		
			100·8	
	3	101		
			100·6	
	4	100·8		
			101·2	
	5	100		
			100·6	
	6	100·2		
			101·2	
	7	101·2		
			101·8	
	8	102		
			101·6	
	9	101		
			100·4	
	10	101·2		
			101	
	11	100·6		
			100·8	
	12	100·2		
			100·4	
	13	100·4		
			100·6	
	14	100		
			101·2	
	15	102		
			101·8	
	16	102·2		
			102	
	17	103		Fever begins
			104	
	18	103·8		
			104	
	19	104·6		One parasitized r.b.c. found in a blood-film
			104·8	
	20	104·6		M. 0·2 % of r.b.c. contained parasites
			104	
	21	103·8		M. 0·4 ,, ,, ,, ,,
			104·8	
	22	105		M. 0·8 ,, ,, ,, ,,
			104·6	E. 1·6 ,, ,, ,, ,,
	23	104·2		M. 2·4 ,, ,, ,, ,,
			104·8	E. 4·0 ,, ,, ,, ,,
	24	104		M. 6·0 ,, ,, ,, ,,
			104·6	E. 6·8 ,, ,, ,, ,,
	25	104		M. 9·6 ,, ,, ,, ,,
			104·2	E. 9·6 ,, ,, ,, ,,
	26	105		M. 9·6 ,, ,, ,, ,,
			104·8	E. —
	27	106		M. 13·6 ,, ,, ,, ,,
			105·8	E. 14·0 ,, ,, ,, ,,
	28	105		M. 14·4 ,, ,, ,, ,,
			102·2	E. 17·6 ,, ,, ,, ,,
20. xii. 1910	29	—		Cow died at 6 a.m.

CONTROL III (*Calf* 23).

Date	Day	Temp. °F.		
		a.m.	p.m.	
30. IV. 1914	1	—	102	Infected *R. appendiculatus* nymphs placed on calf
	2	101·7	102	
	3	101·8	102·4	
	4	102·1	102	
	5	101·8	101·8	
	6	101·4	102·8	
	7	101·2	101·4	
	8	101·6	102·4	
	9	101·8	102·1	
	10	101·2	101·4	
	11	101	101·8	
	12	102·3	102·5	
	13	104	104·8	Fever begins
	14	105·2	104·4	
	15	104·4	106·2	
	16	106	106·2	
	17	106·1	106·2	
	18	105·2	105·6	
	19	103·6	104·2	Parasites in 0·8 % of corpuscles
	20	102·4	103	,, 7·2 ,, ,,
	21	101·8	102·4	,, 10·4 ,, ,,
	22	103·9	104·2	,, 11·6 ,, ,,
	23	105·2	106·5	,, 27·2 ,, ,,
	24	105·7	105	,, 28·8 ,, ,,
	25	106	105·8	,, 22·8 ,, ,,
25. V. 1914	26	105·6		,, 31·6 ,, ,, Calf died

SUMMARY AND CONCLUSIONS.

No drug has been found which will influence the fatal course of East Coast Fever or retard the multiplication of *Theileria parva* in the blood of the affected cattle.

The drugs which were tried with negative results were Trypanblue, Congo red, Tryposafrol, Creosote and Oleum copaivae, Arsacetin, Soamin, "606," Emetine hydrochloride, Mercury salicylate, Mercury succinimide, Quinine bihydrochloride and hydrochloride, Ethylhydrocupreine, Ammonium fluoride, Potassium iodide, Sodium salicylate, Calcium lactate, and Nuclein.

All of our animals died—18 treated and 3 untreated—and showed typical lesions at autopsy. They were all infected by means of ticks (*Rhipicephalus appendiculatus*) which had fed on infected cattle as larvae and nymphs and been placed on the experimental animals as nymphs and adults respectively.

The increase in the number of parasitized red blood corpuscles, but for slight irregularities, proceeds continuously night and day until the animal dies. We have not as yet observed a case ending in recovery.

The accompanying table gives a summary relating to each experimental animal (except XII): the number and kind of ticks which produced infection, the incubation period, the time when the parasites appeared in the peripheral blood, the time when the animals died, and the maximum percentage of parasitized blood corpuscles observed during the course of the disease. The days are all reckoned from Day 1 when the infective ticks were placed upon the cattle.

The expenses of this investigation were mainly defrayed by means of a grant made by the Parliament of the Union of South Africa.

My thanks are due to Dr W. E. Dixon, F.R.S., University Lecturer in Pharmacology, Cambridge, for kindly suggesting the trial of several of the drugs which were used. I am also indebted to my Laboratory Assistant, Mr B. G. Clarke, for much valuable help, especially in the making of the blood counts.

Expt. No.	The ticks which produced infection were	Day on which animal showed fever (= incubation period)	Day on which parasites were first found in animal's blood	Day when animal died	Maximum number of parasitized corpuscles recorded during illness	
I	12 ♂ ♀	14	20	30	46 %	
II	30 ⊙s	13	23	33	8·0 %	
III	40 ⊙s	14	18	29	57·2 %	
IV	12 ♂ ♀	13	18	30	55·2 %	
V	18 ♂ ♀	12	15	29	41·6 %	
VI	7 ♂ ♀	12	19	31	75·8 %	
VII	30 ⊙s	15	19	29	43·6 %	
VIII	12 ♂ ♀	13	20	24	21·0 %	
IX	26 ♂ ♀	14	18	29	84·2 %	
X	14 ⊙s, 8 ♂ ♀	12	16	27	39·2 %	
XI	12 ⊙s	11	15	28	24·0 %	
XIII	9 ⊙s	12	17	30	59·2 %	
XIV	50 ⊙s	11	19	26	36·0 %	
XV	50 ⊙s	12	16	28	47·2 %	
XVI	24 ⊙s	10	17	22	16·8 %	
XVII	50 ⊙s	12	18	25	56·0 %	
XVIII	140 ⊙s	11	15	28	58·8 %	
Control I	13 ♂ ♀	14	19	29	56·0 %	(untreated)
II	19 ♂ ♀	17	19	29	17·6 %	,,
III	? ⊙s	13	19	26	31·6 %	,,
Cow 1	30 ♂ ♀	15	17	32	75·0 %	,,
2	12 ♂ ♀	14	20	30	60·0 %	

Note: The last two experiments are recorded in *Parasitology*, II. pp. 328, 329. These animals were infected by means of *Rhipicephalus evertsi* whereas all of the other animals were infected through our strain of *R. appendiculatus* originally received from Cape Colony through the courtesy of Mr C. P. Lounsbury.

MALLOPHAGA FROM *APTERYX*, AND THEIR SIGNIFICANCE; WITH A NOTE ON THE GENUS *RALLICOLA*.

By LAUNCELOT HARRISON, B.Sc.

Exhibition of 1851 *Research Scholar of the University of Sydney.*

(*From the Quick Laboratory, University of Cambridge.*)

(With 6 Text-figures.)

I.

Through the courtesy of Dr Hans Gadow I have had the opportunity of examining a number of skins of five species of *Apteryx* in the collection of the Cambridge University Museum. From these I have collected at least three species of Mallophaga, which I find to belong to the genus *Rallicola*. These are described below, with some discussion of the genus to which they belong, and of the significance of the occurrence of that genus upon *Apteryx*, from which no Mallophaga have previously been recorded.

The name *Rallicola* was proposed by Johnston and myself (1911, p. 324) for that part of Piaget's genus *Oncophorus* (1885, p. 35) found upon Rallidae, etc., the name *Oncophorus* being invalid, as it had been used by Rudow (1870). A full discussion will be found in our paper (*loc. cit.*). Piaget's genus included forms found upon owls, hornbills, rails and jacanas. The parasites of the two former groups do not seem to have much in common with those of the two latter, nor with each other; and probably should be included in two distinct genera. Those of the two latter groups fall within the limits of our genus *Rallicola*, together with the species from *Apteryx* described below. This genus thus includes species from three host families, which form three compact groups easily separable from one another by constant though quite unimportant differences in form. As a matter of convenience, therefore, I suggest a division into sub-genera, *Rallicola s. str.* confined to Rallidae; *Parricola* found on Parridae; and *Aptericola* on Apterygidae. These divisions may be diagnosed as follows:

Genus *Rallicola*, Johnston and Harrison.

Philopteridae of small to moderate size; of a general form varying between that of *Philopterus* and *Degeeriella*, more resembling the latter; without distinct clypeal suture; with slight to well-marked sexual dimorphism of the antennae; with a definite indication of two distinct articles in the tarsus; with the transverse bands of the abdomen continuous, or divided only by a narrow median line. The best characters are, however, found in the ♂ genitalia, which have a characteristic form, with straight (rarely curved) divergent parameres, having two small lobes at their bases, and a solid median portion, details of which will appear below in the description of the species; and in the genital plate and ventral pleural margins of the eighth segment of the ♀, which have a very characteristic chaetotaxy. The inner margin of the pleuron at its anterior end is produced into a process directed backwards and inwards, which carries three, more rarely two, stout spinous hairs; while the pleuron behind is densely covered with hairs arranged in two or three longitudinal rows. The genital plate is strongly convex, sometimes with a median emargination, and is closely fringed with one or more rows of shorter hairs, the more anterior of which are frequently reduced to small spines. These structures are unusual in the *Ischnocera*, and bear at least a superficial resemblance to those found in some *Amblycera*. The straight divergent parameres of the ♂, embracing a single sac-like median structure, are also reminiscent of the Amblyceran condition; and it would seem as if *Rallicola* were a somewhat primitive Ischnoceran genus.

Rallicola s. str. is confined to the Rallidae, and is found upon all genera from the large forms such as *Fulica, Porphyrio, Aramus*, and *Ocydromus* down to small species of *Rallus* and *Porzana*. It possesses the characters detailed above, and is usually of small size, of the general proportions of a slender *Philopterus*, with the ♂ much smaller than the ♀. The space between the hind border of the signature and the mandibles is uncoloured. Type, *R. attenuata*, Burmeister.

Sub-genus *Parricola*, nov.

Species from the Parridae have the same general facies as those from rails, but are distinctly more slender forms, with little difference in size between the sexes, the ♂ being only very slightly smaller than the ♀. The transverse abdominal bands of the ♂ are entire; of the ♀ divided by a narrow uncoloured line. Type, *Rallicola* (*Parricola*) *sulcata*, Piaget.

Sub-genus *Aptericola*, nov.

Distinguished from the two previous subdivisions by its more robust form. The space immediately behind the signature is closed, except for a narrow median interruption, by two coloured bands, leaving two roughly semicircular clear areas in front of the mandibles. The ♂ is somewhat smaller than the ♀. The transverse bands of the abdomen are entire in both sexes. Type, *Rallicola* (*Aptericola*) *gadowi*, Harrison.

The following key will serve to differentiate these sub-genera:

A.	Uncoloured area in front of mandibles in two semicircular patches, not reaching hind border of signature	*Aptericola.*
AA.	Uncoloured area of usual shape, and extending to signature	*B.*
B.	Slender forms, deeply coloured, sexes of equal size	*Parricola.*
BB.	Broader forms, not usually deeply coloured, ♂ markedly smaller than ♀	*Rallicola s. str.*

Rallicola (*Aptericola*) *gadowi*, n. sp.

As it is not likely that more than one, or at most two, further species will be found in this subdivision, I dispense with the long description which is usually the only safe course in dealing with Mallophaga, and merely emphasise the differences between the three species here described. This, with the help of the figures, will render the species easy of recognition.

The general form of the ♂ will be apparent from Fig. 1. It differs from the ♂ of *A. novae-zealandiae* next described in its more robust form, and in the flat clypeal front, with broadly rounded angles, as well as in the longer parameres and shorter median portion of the genital apparatus, which has a wider and shorter basal plate. The features of the chaetotaxy, which would appear to be characteristic for the subdivision, are the three pairs of hairs upon the metathoracic border, and the short median rows on the abdominal tergites, with an absence of lateral hairs save one at each side of the sixth segment.

The ♀ has the same general form as the ♂, but is larger, as will be seen from the measurements given, has filiform antennae, and the usual difference in shape and chaetotaxy of the hind end of the abdomen (Fig. 2). The females of the three species are easily differentiated by means of the shape of the genital plate, which in this species bears a median emargination, while in *A. novae-zealandiae* it is evenly rounded, and in *A. gracilis* has the shape of a truncated triangle.

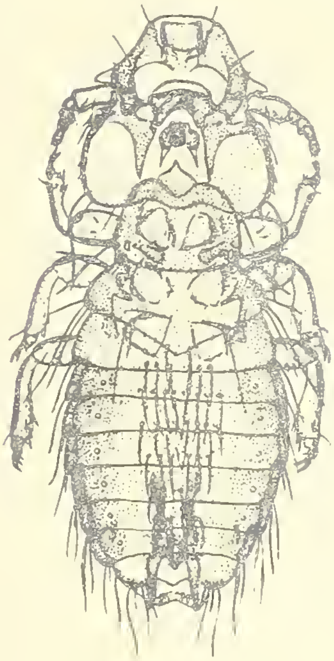


Fig. 1.

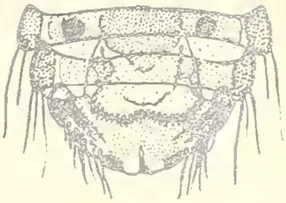


Fig. 2.

Measurements in millimetres.

	♂		♀	
	Length	Breadth	Length	Breadth
Head	0·59	0·62	0·64	0·67
Prothorax	0·17	0·40	0·18	0·44
Metathorax	0·27	0·57	0·27	0·64
Abdomen (from anterior angles) ..	0·82	0·71	1·18	0·84
Total length and greatest breadth	1·76	0·71	2·15	0·84

Several ♂♂ and numerous ♀♀ from skins of *Apteryx australis* in the Cambridge University Museum. I also assign to this species a single ♀ from a skin of *Apteryx mantelli*, which is larger than the type, but shows no differences of specific value. The discovery of the ♂ may prove that this form is distinct.

Rallicola (*Aptericola*) *novae-zealandiae*, n. sp.

The ♂ of this species (Fig. 3) is, as already pointed out, more slender than the last, and has the clypeal front broadly rounded instead of truncate. The general coloration is considerably lighter. But the chief differences, or rather, those best adapted for distinguishing the species, are found in the genitalia. I figure those of the present species (Fig. 4). Unfortunately the ♂ of *A. gadowi* taken for dissection of these parts proved to have broken parameres, and as the males among my material were few, I did not care to sacrifice another. I have not, therefore, figured the genitalia of *A. gadowi*; but with the aid of the dissection, which has lost only the distal halves of the parameres, and of these halves, which happen to be extruded in the type mounted specimen, I am able to make safe comparisons. The genital apparatus consists of a basal plate, with parameres articulated distally, between which lies an undivided mesosome. At the base of each paramere, on the inner side, a short weakly-coloured lobe projects inwards under the mesosome. This lobe is certainly attached to the paramere, but has no appearance of being a normal process upon it, as it is so delicate in

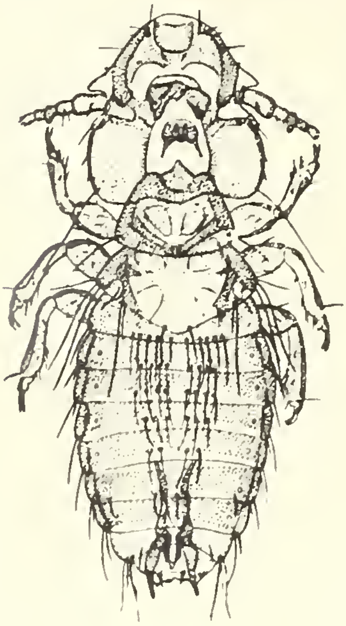


Fig. 3.

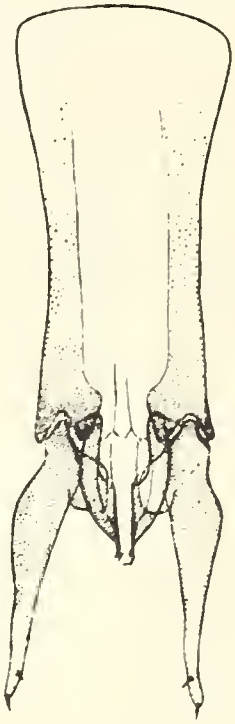


Fig. 4.

comparison. It may represent a reduced endomere. The mesosome comes nearer in general form to that of *Docophoroides* than to any other with which I am acquainted. Its general shape will be seen from Fig. 4. A cylindrical chitinous tube, which is a direct continuation of the ejaculatory duct, runs through and slightly beyond it, constituting the penis, which opens dorsally by a triangular orifice. The genitalia of *A. gadowi* differ from those of *A. novae-zealandiae* in the following details. The basal plate is broader and shorter; the endomeral (?) lobe is distinctly smaller; the mesosome is shorter and slightly broader, with a more heavily chitinised penis; and the tip of the paramere is slightly spatulate instead of filiform, and bears two terminal bristles in place of the customary one.

The ♀ is larger than the ♂, with the usual differences in the hind end of the abdomen (Fig. 5). The genital plate is rounded, and the chitinous bands running forwards from its lateral insertions are not developed.

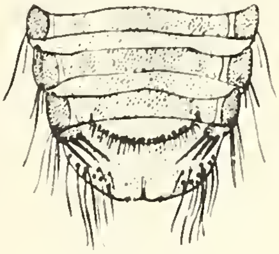


Fig. 5.

Measurements in millimetres.

	♂		♀	
	Length	Breadth	Length	Breadth
Head	0·59	0·57	0·59	0·61
Prothorax	0·17	0·39	0·18	0·39
Metathorax	0·26	0·55	0·26	0·58
Abdomen (from anterior angles) ..	0·84	0·64	1·11	0·79
Total length and greatest breadth	1·68	0·64	2·18	0·79

Numerous ♂♂ and ♀♀ from skins of *Apteryx lawryi* in the Cambridge University Museum. One ♀ and several ⊙ ⊙ from skins of *Apteryx oweni*. One ♀ (straggler) from *Stringops habroptilus*.

Rallicola (*Aptericola*) *gracilis*, n. sp.

This well-marked species is described from a single ♀ taken from a skin of *Apteryx haasti* in the Cambridge University Museum.

Fig. 6 gives the general form. It differs from the females of the two previous species in the narrow and truncate hind end of the abdomen, in the shape of the genital plate, and in some details of the abdominal chaetotaxy. As these details will be obvious on a comparison of the figures, there is no need for a detailed description. The present species is also smaller and more slender than those which precede it. The figure shows the dorsal aspect of the insect to the end of the sixth abdominal segment, the terminal portion being represented as if viewed ventrally.

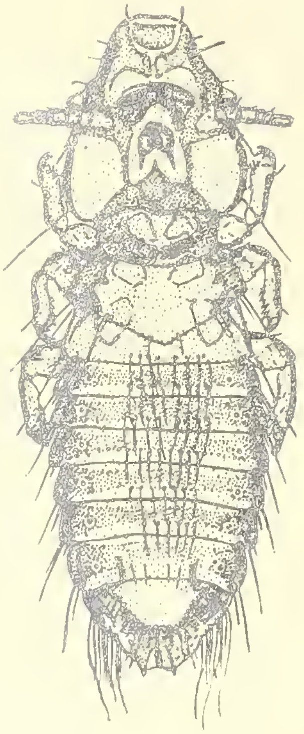


Fig. 6.

Measurements in millimetres.

	♀	
	Length	Breadth
Head	0·60	0·60
Prothorax	0·17	0·42
Metathorax	0·26	0·49
Abdomen (from anterior angles) ..	1·09	0·74
Total length and greatest breadth	2·00	0·74

The types of these three species will be deposited in the Australian Museum, Sydney, New South Wales.

LIST OF HOSTS WITH PARASITES.

Apteryx australis	*Rallicola*	(*Aptericola*)	*gadowi*
,, *mantelli*	,,	,,	,,
,, *lawryi*	,,	,,	*novae-zealandiae*
,, *oweni*	,,	,,	,,
,, *haasti*	,,	,,	*gracilis*
Stringops habroptilus	,,	,,	*novae-zealandiae*

II.

In view of the conclusions which have been reached independently by Kellogg and myself (*vide* Harrison, 1914, and references to Kellogg's papers quoted therein; also Kellogg, 1914, pp. 259–60) that the relations of Mallophagan parasites are intimately bound up with the phyletic relationships of their hosts, a discussion of the significance of the occurrence upon *Apteryx* of the parasitic genus *Rallicola* is of considerable interest.

I do not think that there can be any reasonable doubt as to the species described above being true parasites of *Apteryx*. I have collected them from skins of five species, and, in the case of two of these species, from several individuals. The only other Mallophaga found upon these skins were a few immature *Menopon*, which were too young to afford any idea of their affinities. I have examined the good series of New Zealand birds contained in the Cambridge collection, and have not found these Mallophaga upon any other form, save a single individual on one out of six skins of *Stringops* examined. This accidental occurrence is easily understood, as *Stringops* and *Apteryx* are both nocturnal, and hide during the day in hollow stumps, etc. Occasional transference may take place when the two species are hiding together in one refuge, or even when one occupies a hollow that has recently been in possession of the other. The positive evidence is, therefore, fairly conclusive, and it is supported by the negative fact that no other Ischnoceran parasites were found upon the skins. No family of birds is without Ischnoceran Mallophaga, so that, as no other forms have been found which might be taken as the normal parasites, it is reasonable to conclude that the sub-genus *Aptericola* contains the normal Ischnoceran parasites of the Apterygidae.

There can be no possible question as to the correctness of my placing these parasites within the genus *Rallicola*. However much uncertainty may exist as to the value of the present classification of Mallophaga, there is no doubt that *Rallicola* is a good and distinct genus, well-defined, and clearly marked off from all other Ischnocera; and there is equally no doubt that the sub-genus *Aptericola* is merely a group within the genus *Rallicola*, conveniently distinguished by its robust form. *Rallicola* is, as I have stated above, confined to rails, and found upon all sorts and sizes of rails over the length and breadth of the globe; and I have reasons, partly stated above, for considering it a somewhat primitive Ischnoceran genus, certainly more primitive than *Philopterus* and *Degeeriella*, which appear to have developed from the same branch of the original stock.

Only one other Mallophagan genus, *Pseudomenopon*, is found solely upon rails, and is generally distributed amongst them. This is, so far, monotypic, but will probably be found to contain a number of species when it is critically examined, as has been the case with other genera (e.g. *Docophoroides* and *Giebelia*). I have not succeeded in finding *Pseudomenopon* upon *Apteryx*. A few species of *Lipeurus*, *Philopterus*, *Degeeriella*, and one of *Laemobothrium* are also found upon rails, but these would seem to be comparatively late acquisitions, as they are not generally distributed, and have chiefly been found upon *Fulica*, *Gallinula*, and *Porphyrio*.

The robust form of the species of *Rallicola* from *Apteryx* may also possess some significance. In general, large Mallophaga are found upon large birds. This is not by any means always true. If it were, we should expect to find the largest Mallophagan species upon the ostrich, whereas it occurs upon a condor. Similarly *Ricinus*, which comprises fairly large species, is found chiefly upon small passerine birds. But, in general, when a genus is well distributed over a considerable number of nearly related hosts, the size of the parasite is roughly proportional to the size of the host. Thus species of *Lipeurus* found upon albatrosses are larger than those found upon the larger petrels; and these in their turn exceed in size those found upon the little storm petrels. The largest species of *Philopterus* are found upon ibis, storks, and vultures; of *Colpocephalum* on storks, cranes, hornbills, etc.; of *Goniodes* upon peafowl and tragopans; and many similar instances might be quoted. Arguing on general grounds, then, I should, had these species of *Aptericola* been submitted to me without any data as to the host, have given the opinion that they came from a group of large ralline birds. But no species of *Apteryx* is very large, and certain of them are smaller, bulk for bulk, than some of the larger rails, as, for instance, some species of *Ocydromus*, which carry *Rallicola* of the ordinary small type. A possible inference is that *Apteryx* is an offshoot of a larger-statured stock. Since it is generally agreed that the Apterygidae and

Dinornithidae are closely related, it is not so improbable as it may seem at first sight that *Aptericola* was the type of Ischnoceran Mallophaga found upon the Dinornithidae.

Finally I should like to discuss the Mallophagan parasites of the ostrich, rhea, and emu, to which, of living birds, *Apteryx* has hitherto been considered most closely related. I have already (1914, pp. 9–10) written something about the species found upon these three hosts. I have again looked into the matter carefully, and I am still of the opinion that these species, and their hosts with them, had common origin. In any case the Mallophaga of the larger ratite birds belong to a different family, and have no close relationship to the genus *Rallicola*. So the parasites of *Apteryx* differ radically from those of the remaining Ratitae, and are closely akin to those of the Rallidae.

I have tried, in the preceding five paragraphs, to put an unprejudiced statement of the case. The points I have wished to make in these paragraphs may be stated briefly as follows:

(i) *Aptericola* is a normal parasite of *Apteryx*.

(ii) *Aptericola* is certainly, at most, a sub-genus within the genus *Rallicola*.

(iii) *Rallicola* is a universal parasite of rails, and of nothing but rails, except for the Parridae and Apterygidae.

(iv) *Aptericola* possibly indicates the type of Ischnoceran parasite that existed upon the Dinornithidae.

(v) The Mallophaga of the remaining Ratitae have nothing in common with those of *Apteryx*.

The inference that I draw from these conclusions is that *Apteryx* (and possibly *Dinornis* also) is more closely akin to the Ralli than to any other living birds. Subsidiary deductions are that the Parridae are ralline rather than limicoline; and that the Ralli are probably distinct enough to justify ordinal rank.

Taking the latter first, though the position of the jacanas has been the subject of some discussion they are, in most recent classificatory schemes, definitely included amongst the Limicolae. This order has, however, the best limited groups of Mallophaga that we can point to. No person with any knowledge of the group could fail to determine at sight a parasite in any of the genera found upon limicolines, or, perhaps I had better say, upon the Charadriiform complex, as having come from a Charadriiform host. (With this group, by the way, the parasites of the Pterocles and Columbae show no close affinity.) The Mallophaga of the jacanas do not fall within these well-marked limits.

As to the position of the Ralli, they possess as their most widely distributed and characteristic parasites two well-marked genera, *Rallicola* and *Pseudomenopon*, one in each of the sub-orders of Mallophaga. *Rallicola* would seem to be a somewhat primitive genus, certainly more primitive than *Philopterus* and *Degeeriella*, the remaining genera of the same family; while the relation of *Pseudomenopon* to the other menoponid genera cannot, in the absence of any form showing an intermediate condition, be stated. The fact that *Pseudomenopon* does not occur on either Parridae or Apterygidae may indicate that it is of more recent development than *Rallicola*. An important negative fact is the non-occurrence of *Philopterus* upon rails. This genus, which is generally looked upon as the most specialised of the more specialised sub-order, is almost universally distributed among birds. The only important groups that are without it are the Galliform complex, comprising tinamous, fowls, pigeons, the hoatzin, and, on Mallophagan evidence, the penguins; and the Ratitae. Three or four species of *Philopterus* have certainly been described from some of the larger rails, but I have carefully searched a large number of species of ralline birds from all parts of the world without finding *Philopterus*; while all yielded *Rallicola*, and many *Pseudomenopon*. It is fairly obvious, then, that *Philopterus* can only have been acquired at a comparatively recent date by those species which possess it. Species of *Degeeriella*, *Lipeurus*, and *Laemobothrium* are also too few in number and too circumscribed in distribution to be included in other than the same category. The intrinsic parasites of the Ralli stand, then, in an isolated position with regard to the remaining Mallophaga. And all the evidence of Mallophagan distribution points to the conclusion that the condition of the parasites is intimately connected with the phylogenetic relationships of the hosts, and reflects these relationships to a greater or less extent. Consequently I cannot avoid the conclusion that the Ralli occupy an isolated position, which should entitle them to at least the same rank as the similarly isolated Galliform complex.

It may be as well, at this point, to clearly define my position in making such statements as to bird relationships as that conveyed in my last sentence. These statements are made frankly upon the evidence afforded by the parasites. They are, consequently, not comparable with the statements of a morphologist, based upon structural considerations; but are to be looked upon simply as suggestions, which I believe may be well founded, but which, until they receive morphological confirmation, must remain simply suggestions. I may state them with an appearance of dogmatism, but I clearly understand that they are governed in every case by the above limitation. My excuse for making them is that the phyletic relations of birds have always presented a very difficult problem, and that none of the customary means has produced a satisfactory solution. So when I find that bird parasites, owing to their peculiar biological condition, seem to shed some light upon this problem, I think it worth while to put these indications on record. The morphologist can confirm or refute them at his leisure.

With this much explanation I proceed to the final question—Is *Apteryx* a rail? If not, how does it come to possess ralline parasites? The mature opinion of Prof. Kellogg, after twenty years' study of Mallophaga, is that "the host distribution of these wingless permanent ectoparasites is governed more by the genetic relationships of the hosts than by their geographic range, or by any other ecologic conditions" (1914, p. 259). That opinion is based on—"The fact, proved by abundant cases, that two host species of wholly distinct geographic range and with no possible opportunity for contact such as would permit of the migration of wingless parasites from one to the other, may have, nevertheless, one or more parasitic species common to them both, is associated almost always with the further fact that these common hosts are closely related genetically." Kellogg instances only the occurrence of the same parasitic species on two geographically segregated but phyletically connected hosts. In my paper (1914) published a month after Kellogg's, but which had gone to press more than a month before it, I carry the hypothesis further; and apply it to the case of closely related parasitic species upon closely related hosts. And though I cannot lay claim to the same wide knowledge of Mallophagan species that Prof. Kellogg possesses, I had nevertheless been studying the group for some five years, purely from this point of view. Only one other explanation of the distribution of Mallophaga can be put forward, namely that it is due to convergence. I have not overlooked this possibility, but I do not find any evidence of this cause myself, and I do not think that the most ardent advocate of convergence, were he to look carefully into the actual conditions of Mallophagan distribution, would claim these conditions as the result of convergence.

The only alternative is to believe that *Apteryx* and the rails are closely connected phyletically, unless one or other of the groups has acquired these particular parasites by some accidental transference. This supposition may be dismissed as far as the rails are concerned.

Rallicola occurs, as I have already pointed out, on all rails from *Ocydromus* to *Porzana*. Its occurrence is far too general for it to have been accidentally acquired. But with *Apteryx* the case is somewhat different. There are but six species of the genus, and I have described only three species of *Aptericola* taken from five of them. These are small numbers, and the suggestion of straggling at a comparatively recent date might be put forward. But *Aptericola* is, after all, a rail parasite, and could only have straggled from some ralline bird. New Zealand is rich in rails, and I have examined these with some interest, to see if any robust form such as *Aptericola* might be found upon them. I have collected Mallophaga from five species of *Ocydromus* from New Zealand itself; as well as from *O. sylvestris* of Lord Howe Island. A species of *Rallicola* has been described by Piaget from *O. lafresnayanus* of New Caledonia. I have also collected species of *Rallicola* from *Porphyrio*, *Hypotaenidia*, and *Porzana* from New Zealand. But in all these cases the parasite belongs to the small rail-infesting type; so it is not probable that *Apteryx* acquired its parasites from any existing rail. *Notornis* certainly remains unexamined, but there is no reason to suspect that its parasites would prove much different from those of *Porphyrio*. Moreover, the negative evidence, as I have stated above, of the absence of any other Ischnoceran parasite is in itself a very good reason for believing that *Aptericola* is and always has been the normal Ischnoceran parasite.

I conclude, then, that *Apteryx* is nearer akin to the Ralli than to any other living birds. The possibility of this relationship has already been foreshadowed by Fürbinger; and arguments for it have been set out at some length in Gadow's systematic volume in Bronn's *Thier-Reichs*, in both cases upon morphological grounds.

REFERENCES.

Harrison (1914). The Mallophaga as a possible clue to bird phylogeny. *Australian Zoologist*, i. pp. 7–11.

Johnston and Harrison (1911). Notes on some Mallophagan generic names. *Proc. Linn. Soc. N.S.W.* xxvi. pp. 321–328.

Kellogg (1914). Ectoparasites of mammals. *Amer. Naturalist*, xlviii. pp. 257–279.

Piaget (1885). *Les Pédiculines*, Essai Monographique, Supplément. Leyden.

Rudow (1870). Beobachtungen über die Lebensweise und den Bau der Mallophagen oder Pelzfresser, sowie Beschreibung neuer Arten. *Zeitschr. f. d. ges. Naturw.* xxxv. pp. 272–302.

THE RESPIRATORY SYSTEM OF MALLOPHAGA.

By LAUNCELOT HARRISON, B.Sc.
Exhibition of 1851 *Research Scholar of the University of Sydney.*

(*From the Quick Laboratory, University of Cambridge.*)

(With 21 Text-figures.)

CONTENTS.

INTRODUCTORY.

THE respiratory system in Mallophaga has not hitherto been described in detail. Kellogg (1896, p. 45) gives the disposition of the main trunks in *Tetrophthalmus*, together with a figure; Snodgrass (1899, p. 170) adds nothing to Kellogg's account; Fulmek (1907) dismisses the tracheal system with a paragraph; Shipley (1909) gives a detailed figure for *Goniodes tetraonis* which is neither complete nor altogether exact; and Mjöberg (1910), although devoting several pages of his morphological section to the respiratory system, is chiefly concerned with the occluding apparatus of the stigmata. He does, however, figure the main trunks in *Eutrichophilus*, and the occluding apparatus in *Gyropus ovalis*; and makes certain general statements which may be summarised as follows:

There are two main tracheal trunks, united behind by a bow-shaped transverse branch. Prothoracic stigmata have only been demonstrated in the Gyropidae, the Trichodectidae, and *Tetrophthalmus.* The abdominal stigmata are dorsal, and mostly in segments 2–7.

The value of this, the most recent statement of the tracheal condition in Mallophaga, may be gauged from the facts that I set out in detail below, namely that the two main trunks are only exceptionally united by a posterior transverse commissure; that prothoracic stigmata are universally present; and that the abdominal stigmata are in almost the whole of one sub-order found upon segments 3–8, that in at least one case they are all ventral, and that in two genera there are but five pairs in place of the usual six.

Possibly the difficulty of satisfactorily demonstrating the tracheal system has been the reason for the somewhat cursory treatment it has received. By the employment of suitable methods, however, I find that it is possible to trace the tracheal supply in great detail. As a superficial examination disclosed certain fundamental differences in the number and arrangement of the stigmata, and in the disposition of the tracheal trunks, I have thought it worth while to investigate the whole respiratory system as fully as the material available to me has allowed.

METHOD OF EXAMINATION.

Living material is essential if the best results are to be obtained. In some forms, where the main trunks are of fairly considerable size, and the taenidia of sufficient strength to resist collapse on treatment with reagents, specimens cleared in potash and mounted into balsam show the more important trunks and branches. *Heterodoxus*, *Tetrophthalmus*, and *Docophoroides* give good results with this treatment. I have seen some preparations of Mr B. F. Cummings in which acid fuchsin has been employed after potash with fair success. But for most genera, and for detail in any of them, live material is desirable. If the living insect be killed and dehydrated by immersion in absolute alcohol for about ten minutes, and then cleared and mounted, the tracheal tubes remain filled with air, and are very easily followed. Such a preparation is, however, not permanent, as balsam gradually replaces the air; but it will usually keep in good condition for several days. A still better method is to put the living insect direct into dilute glycerine under a coverslip, as the glycerine infiltrates the tracheae at a much slower rate, and has sufficient clearing action to render the smaller branches easily visible. Such a preparation will remain in good condition for several weeks. With pale forms, and with newly moulted individuals of darker species, good results may be obtained by examining the living insect under the pressure of a small cover-slip, without any mounting medium. *Menacanthus pallidulus* of the domestic fowl is a favourable species for examination in this way.

In addition to these methods for examination of the whole insect, I have made use of both dissections and serial sections in studying the stigmata, and the latter have also been used to verify certain other points, and for minute structure.

TRACHEAL SYSTEM OF *MYRSIDEA CUCULLARIS*.

As a basis for the comparisons which will follow, I give a detailed account of the distribution of tracheae in *Myrsidea cucullaris*. Figure 1 shows their general disposition in an immature individual of the second instar. The only difference between this stage and the adult is that in the latter the minor branches are more numerous, and their ramifications wider. The alimentary canal is indicated in light stippling, which has been varied sufficiently to differentiate the several regions.

It will be seen that the tracheae are disposed in two main longitudinal trunks; and that they open upon the surface by seven pairs of stigmata, one in the prothorax, and six in the abdomen. The prothoracic stigmata are ventral, behind the middle of the segment, at the junction of the lateral flange with the thicker median portion. The six pairs of abdominal spiracles pierce the pleura of segments 3–8, the first five pairs being dorsal, the sixth ventro-lateral.

The main trunks are not straight, but are bent outwards to form a sharp angle opposite each stigma, the two being connected by an irregularly sinuous stigmatic branch. Similar branches occur in the first and second abdominal segments, but end blindly. They evidently represent the stigmatic branches of these segments, the spiracles themselves having disappeared. On entering the thorax the main trunks converge on either side of the crop, then diverge sharply to the prothoracic stigmata. The trunks coming from the head meet those of the thorax and abdomen at a little distance from these stigmata, and the two sets are connected by short cross-pieces so as to form a complete triangle on either side. The tracheae forming these triangles are the largest in the body. The main trunks on entering the head diverge about the sides of the brain, coming together a little at the sides of the tentorium which is here present, and are continued forwards into the dorsal part of the frons, where they break up into many fine

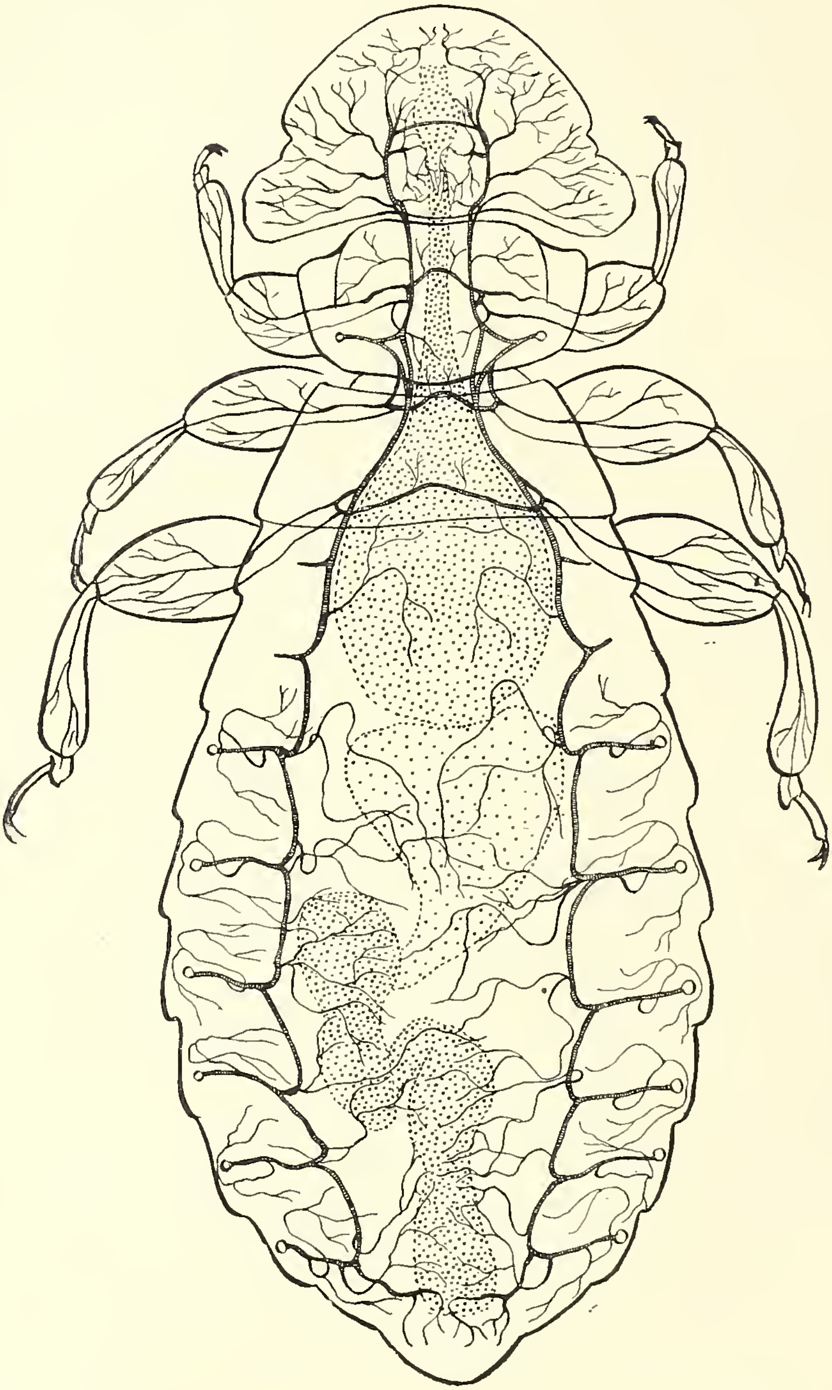


Fig. 1. Tracheal system of *Myrsidea cucullaris*.

twigs among the muscles. Similarly at the hind end of the abdomen the main trunks continue backwards beyond the last stigmatic branch, and break up into fine twigs dorsal to the rectum.

The tracheal branches of the head have the general arrangement shown in the figure. The most posterior pair of branches comes ventrally from the main trunks in the anterior part of the prothorax, and the branch of each side turns outwards and breaks up among the temporal muscles, both dorsal and ventral. Just within the head, small branches are given off internally to the oesophagus. Two large branches on either side run out to the lateral regions of the head. At the level of the anterior cornua of the brain each main trunk divides into dorsal and ventral branches. The dorsal gives off an internal branch which serves the pharynx and brain; and is continued forwards to the dorsal region of the forehead. The ventral gives off an internal branch which meets its fellow of the opposite side to form a commissure running along the anterior margin of the tentorium; and runs forwards and downwards itself to be distributed to the mouth-parts. Part of the internal dorsal branch of either side passes up through the gap between the cornua of the brain, dividing into two, so that four vessels run longitudinally backwards closely applied to the brain, giving off smaller branches which ramify over the surface.

In the prothorax a triangle is formed internal to each stigma, as already stated. The main trunks here lie nearer the dorsal than the ventral surface, and in front of the triangles a commissure descends ventrally so as to underlie the prothoracic ganglion, which is innervated by small branches from it, and gives off two branches to each prothoracic leg. The mesothoracic commissure comes off from the outer sides of the triangles, passing downwards and backwards, and exhibiting precisely the same relations towards the mesothoracic ganglion and legs. The metathoracic commissure lies at the back of the segment, passing below the crop, and innervates the corresponding ganglion and legs. I can find no indication whatever of the survival of any remnant of wing tracheae, unless the inner sides of the triangles can be looked upon as such. Nor is there any indication of stigmata, or of stigmatic branches, in either meso- or metathorax.

Metameric arrangement of the tracheae, which was not obvious in the head and fairly well marked in the thorax, becomes much more definite in the abdomen. The typical constituents on each side of any segment are (*a*) the portion of the longitudinal trunk contained within the segment; (*b*) the stigmatic branch; (*c*) the ventral branch; (*d*) the dorsal branch. A separate visceral element is not present. In the first and second segments the stigmatic branches are short, and end blindly, there being no corresponding stigmata. In the following six segments the typical arrangement is developed. The ventral branches arise in every case from the stigmatic branches, run towards the lateral margin of the abdomen, and turn ventrally, dividing into two main branches which are of much greater extent in the adult than in the young form figured. The dorsal branches arise from the main trunks in front of the corresponding stigmatic branches. These dorsal and ventral branches become greatly divided, and are distributed to all the body organs in an abundance of smaller branches, those of opposite sides freely mingling and crossing, but there is no anastomosis as far as visible branches are concerned, though a capillary anastomosis may be present.

General Account—Introductory.

For purposes of comparison I have examined species of the following genera:

Amblycera.

Ancistrona
Boopia
Colpocephalum
Eomenopon
Eureum
Gliricola
Gyropus
Heterodoxus
Laemobothrium
Latumcephalum
Machaerilaemus
Menacanthus
Menopon
Myrsidea
Nitzschia
Pseudomenopon
Ricinus
Somaphantus
Tetrophthalmus
Trimenopon
Trinoton

Ischnocera.

Akidoproctus
Austrogoniodes
Degeeriella
Docophoroides
Giebelia
Goniocotes
Goniodes
Heteroproctus
Lipeurus
Nesiotinus
Ornithobius
Oxylipeurus
Pectinopygus
Philopterus
Physconella
Pseudonirmus
Psittaconirmus
Rallicola
Trabeculus
Trichodectes

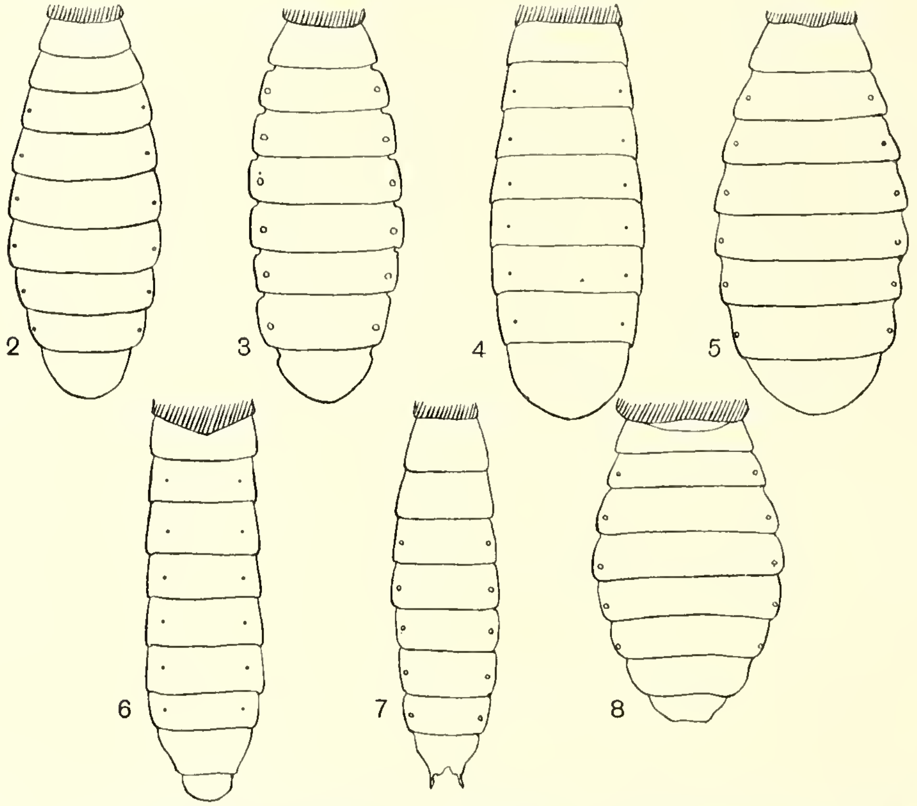
For opportunity to examine specimens of *Nitzschia*, *Trimenopon*, *Eureum*, *Physconella*, and *Nesiotinus* I am indebted to Messrs Gahan and Cummings of the Entomological Department, Natural History

Museum. Living material has, however, not been available in the majority of cases, but the forms which have been examined in detail show such a remarkable constancy in their tracheal arrangement that nothing of any great interest and importance is likely to result from further detailed comparisons. These forms include species of *Glirieola*, *Gyropus*, *Heterodoxus*, *Menopon*, *Menacanthus*, *Myrsidea*, *Rieinus*, *Degeeriella*, *Goniodes*, *Gonioeotes*, *Lipeurus*, and *Philopterus*. The genera which I have not been able to examine are *Damalinia*, *Eutrichophilus*, *Triehophilopterus*, *Eurytriehodectes*, *Philoeeanus*, *Kelloggia*, *Ornieholax*, *Bothriometopus*, *Troehiloecetes* and *Philandesia*. Of these the first four will certainly not differ very much from *Triehodeetes*; the fifth, sixth and seventh, and eighth from other Giebeliidae, Goniodidae and Akidoproctidae respectively; and the ninth from *Rieinus*. *Philandesia* may prove on examination to present some features of interest, but it is the only distinctive genus excluded from my examination.

The generalisations which I shall proceed to make as to the number and disposition of the stigmata and main tracheal vessels are based, then, on observations of species belonging to forty-one genera in a total of fifty-one. The ten not examined are in the majority of cases monotypic; in seven cases only recent cleavages from larger genera with which they show a very close agreement; and number less than twenty species in a total of close upon two thousand.

THE STIGMATA.

In all Mallophaga except *Gliricola* and possibly *Trimenopon* there are seven pairs of stigmata, one prothoracic and six abdominal. *Glirieola* has but five pairs of abdominal stigmata. I have been able to examine only mounted specimens of *Trimenopon*, and in these I have not succeeded in demonstrating the existence of a sixth abdominal pair. I also find one species of *Trichodeetes*, *T. divaricatus*, Neumann, with only five pairs of stigmata apparently present. I do not know of any other exception to this general statement, which, although several morphological accounts of the Mallophaga have been published, has not been made before. All that Snodgrass (1899, p. 170) says about the stigmata is: "Spiracles are situated laterally on the dorsal side of the abdominal segments, and *in some species*, as *Menopon titan*, there is a spiracle on each side of the prothorax." The italics are mine. Mjöberg (1910), as already stated, only demonstrated prothoracic stigmata in a few genera. Shipley (1909, p. 316) mentions that the prothoracic stigmata are difficult to see. It may be noted in passing that Kellogg (1903, p. 90) allows only five pairs of abdominal stigmata to *Nesiotinus*, but this is an error, as I have satisfied myself by personal examination, the six pairs being present in the usual position. (With the still more extraordinary error which has been made in describing the thorax of this insect I am not here concerned.)



Figs. 2–8. Abdomen, to show stigmata, of: (2) *Menopon*; (3) *Heterodoxus*; (4) *Ricinus*; (5) *Gyropus*; (6) *Lipeurus*; (7) *Gliricola*; (8) *Trimenopon*.

The abdominal stigmata are, with the exceptions mentioned above, constantly twelve in number. Their disposition differs in the two sub-orders. In the Amblycera (Fig. 2), with the exception of the Boopidae (including *Boopia*, *Heterodoxus*, and *Latumcephalum*) (Fig. 3), the Ricinidae (including *Ricinus* and *Trochiloecetes*) (Fig. 4), and *Gyropus* (Fig. 5), the abdominal stigmata open upon the third to the eighth segments. In the two families mentioned, in *Gyropus*, and in the whole of the Ischnocera (Fig. 6), the stigmata open upon the second to the seventh segments. In *Gliricola* (Fig. 7) and *Trimenopon* (Fig. 8), segments three to seven carry the spiracles; but in the latter, though the first pair is reckoned as occurring on the third segment, the first segment is so much incorporated with the thorax that only a small portion of the tergum, which does not reach to the sides of the abdomen, remains. In the Boopidae there is also a suggestion of the inclusion of an abdominal segment with the thorax, as a sternite quite distinct from that of the metathorax is visible on the under side, for which there is no corresponding tergum on the dorsal surface. It is reasonable to conclude that the same cause operates in the case of both Ricinidae and the ISCHNOCERA, and that the difference in stigmatal arrangement is due to the suppression of the first abdominal segment, or its incorporation with the thorax. This condition is strongly suggested in *Trichodectes*. The segments in front of those which bear the stigmata usually show small scars in the position which the spiracles would have had (Fig. 9), and indicate that the Mallophaga, or their ancestors, originally had two additional pairs of abdominal stigmata.

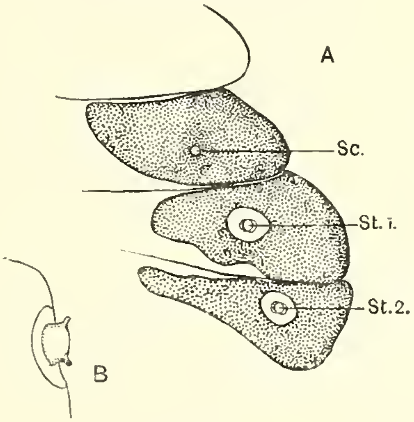


Fig. 9. *Philopterus brevicollis*; (*A*) Part of first three abdominal segments to show stigmata and stigmatal scar; (*B*) sixth abdominal stigma in profile.

The abdominal stigmata open indifferently through terga, or pleura, or the softer integument separating the two. They are almost invariably dorsal, and usually perforate the terga in the ISCHNOCERA; but in the AMBLYCERA the more posterior tend to become lateral, or even ventral. In *Gliricola* all are ventral, piercing the pleura. In many species, more especially of ISCHNOCERA, each is surrounded by a clear pustule (Fig. 9). In others, as, for example, *Goniodes* and *Trinoton*, heavy pleural or tergal incrassations surround the stigmata. They are all alike in form, an external circular or ellipsoidal opening leading into a larger vestibule which in turn opens into a second chamber, or bulla, the latter receiving the narrow end of the stigmatic trachea.

The external aperture is usually circular, sometimes ellipsoid, in which case the long axis is usually transverse, or slightly oblique. Its size varies considerably, as the following table of measurements shows. Where the aperture is not circular, the longer axis has been measured.

DIAMETER OF ABDOMINAL SPIRACLES IN MILLIMETRES.

Lipeurus circumfasciatus	0·006	*Oxylipeurus sinuatus*	0·014
Giebelia hexakon	0·008	*Trabeculus heteracanthus*	0·014
Trichodectes appendiculatus	0·011	*Gyropus ovalis*	0·015
Goniodes curvicornis	0·011	*Lipeurus crassus*	0·015
Lipeurus mutabilis	0·011	*Ornithobius fuscus*	0·017
Lipeurus diversus	0·011	*Heteroproctus hilli*	0·017
Degeeriella cingulata	0·011	*Docophoroides brevis*	0·017
Rallicola bisetosa	0·011	*Pseudomenopon tridens*	0·017
Aptericola gadowi	0·012	*Trichodectes setosus*	0·028
Goniocotes fissus	0·012	*Lipeurus ferox*	0·033
Philopterus occidentalis	0·012	*Heterodoxus longitarsus*	0·039
Gliricola gracilis	0·013	*Philopterus brevicollis*	0·039
Latumcephalum macropus	0·014	*Tetrophthalmus titan*	0·047
Lipeurus asymmetricus	0·014	*Laemobothrium circi*	0·055

A study of this table shows that, in general, the stigmatic apertures of the ISCHNOCERA are considerably smaller than those of the AMBLYCERA. The exceptions which stand out prominently are *Trichodectes setosus*, which, in common with most species of the genus, possesses large stigmata; and *Philopterus brevicollis*, which belongs to a small group characterised, amongst other things, by the size of the stigmata. But it is not until after eight Ischnoceran genera are listed that the first Amblycera appear, and these are *Latumcephalum* and *Gliricola*, both very small forms. *Laemobothrium* caps the list, but in proportion to its size has small stigmata. The same may be said of *Ricinus*. Forms found upon mammals have, in both sub-orders, larger stigmata than those found upon birds. Seen in profile (Fig. 9, B) the stigma exhibits a rigid rim standing up from the general surface. The external opening is never protected by hairs, though in *Tetrophthalmus* (Fig. 10) certain bristles occur in close proximity.

The prothoracic stigmata differ, as a rule, in their larger size, and in having the actual external aperture slit-like rather than circular or ellipsoid. Several forms are shown in Figs. 11, 12, 13, 14. They are situated ventrally upon the prothorax, close to the postero-lateral angle in the Ischnocera; and posteriorly where the wing joins the body in the Amblycera. The Akidoproctidae and some species of *Trichodectes* have these stigmata lateral.

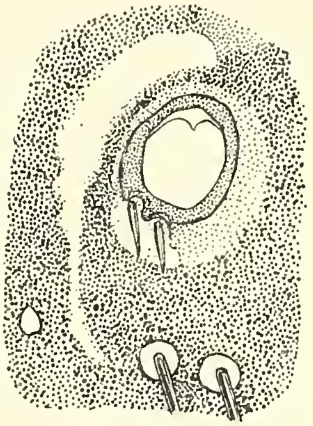
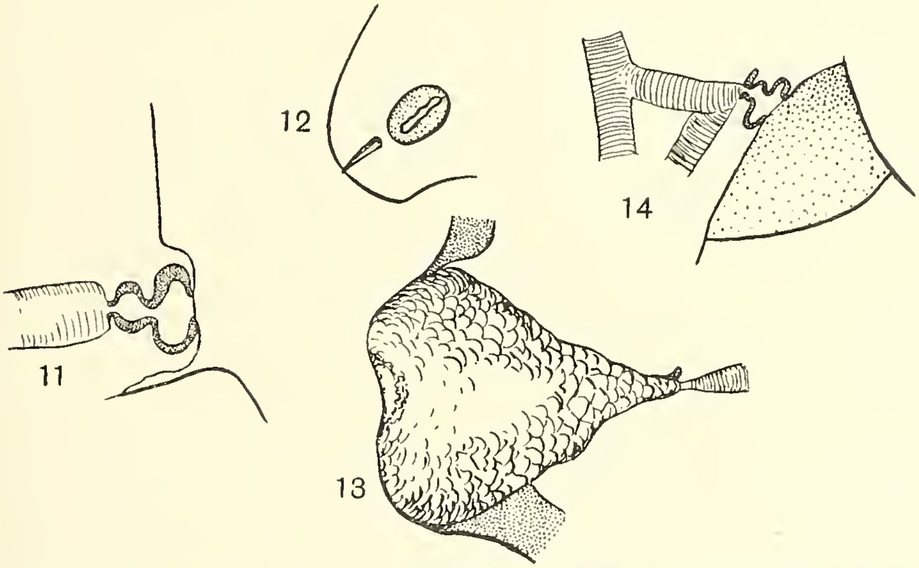


Fig. 10. Abdominal spiracle of *Tetrophthalmus titan.*



Figs. 11–14. Prothoracic stigmata of: (11) *Heteroproctus hilli*; (12) *Aptericola gadowi*; (13) *Trichodectes setosus*; (14) *Heterodoxus longitarsus* (11, 13, and 14 in optical section).

The vestibule, which lies below the external aperture, is very variable in shape and sculpture. The commonest form has the shape of a somewhat flattened sphere, sunk below the surface, with which it is continuous at the margin of the external aperture. Sometimes, as in *Tetrophthalmus*, the chamber projects above the surface as a hemispherical protuberance, on the summit of which is the spiracle. In *Gyropus* it has somewhat the shape of a kettledrum, the rim of which is flush with the surface, and the centre of the flat surface pierced by the spiracle. In *Trichodectes* the arrangement at the surface is the same, but the rim is thickened and sculptured, and the chamber the shape of an elongate cone. The prothoracic vestibules are often remarkably different from those of the abdomen. In *Trimenopon* a very long cylindrical vestibule with reticular pattern on its thick chitinous wall connects the external opening with the bulla. In *Trichodectes setosus* (Fig. 13) the vestibule is enormously enlarged, with scaly sculpture. Contrary to what is the case with the abdominal stigmata, the prothoracic vestibule is proportionately larger in the Ischnocera than in the Amblycera, as the following diametric measurements show.

Measurements in Millimetres of Prothoracic Vestibules.

Trichodectes setosus	0·075	*Goniodes curvicornis*	0·019
Heteroproctus hilli	0·039	*Gliricola gracilis*	0·019
Lipeurus asymmetricus	0·033	*Heterodoxus longitarsus*	0·019
Ornithobius fuscus	0·030	*Lipeurus fasciatus*	0·017
Aptericola gadowi	0·028	*Pseudomenopon tridens*	0·017
Docophoroides brevis	0·028	*Trabeculus heteracanthus*	0·014
Goniocotes gigas	0·028	*Latumcephalum macropus*	0·014
Oxylipeurus sinuatus	0·025	*Rallicola bisetosa*	0·013
Philopterus occidentalis	0·019	*Giebelia hexakon*	0·013

The sculpture of the vestibule differs considerably in different forms. A common type in the Ischnocera is that in which the whole inner chitinous surface is raised into parallel ridges. In other genera the sculpture is reticulate, or scaly, the scales in some cases being so small and elongate as to look like hairs. This sculpture probably serves to hinder dust particles from entering the tracheae.

The term *bulla* I employ for what is usually a distinct chamber internal to the vestibule, which gives support to the occluding apparatus, and with which the stigmatic branch of the trachea actually connects. In some forms, e.g. *Heterodoxus*, there is little distinction between vestibule and bulla; in others, as *Trichodectes*, the bulla is reduced to a narrow chitinous tube. The precise relations of these parts will be seen in Figs. 16, 18 and 19.

The occluding apparatus has received attention only from Mjöberg. He has published (1910, p. 221) a diagrammatic figure of this apparatus in *Gyropus ovalis*, showing a chitinous tab resting upon an extremely narrow tracheal neck, and having attached to it distally a muscle, the other insertion of which is not indicated beyond a vague statement that it runs to the integument. Similar figures are given for various Anoplura. Mjöberg points out (*l.c.* p. 222) that his observations are confined to the AMBLYCERA, the opaque integument hindering them in the ISCHNOCERA. I was for some time at a loss to reconcile Mjöberg's statement and figure with my own observations in sections of Ischnoceran forms, or to understand exactly how occlusion was brought about. His figure affords no apparent fulcrum for the leverage exerted by the tab. After some difficulties, due to the small size of the structures involved, and the very serious hindrance to the cutting of good sections which the thickness of the chitinous cuticle presents, I have succeeded in demonstrating at least two types of occluding apparatus, a simple and a more complex; with possibly some intermediate forms, but on these my observations are not complete.

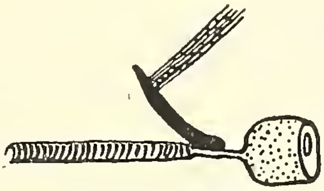


Fig. 15. Occluding apparatus of *Gyropus ovalis*, after Mjöberg.

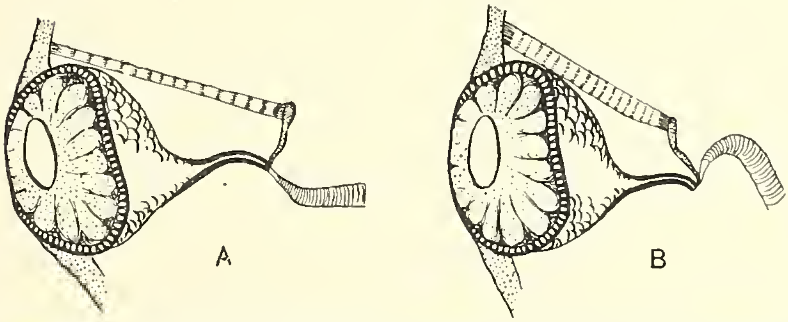


Fig. 16. Stigma and occluding apparatus of *Trichodectes longicornis*, semi-diagrammatic; (*A*) open; (*B*) closed.

The simple type is that figured by Mjöberg for *Gyropus ovalis*. I give his version in Fig. 15. Fig. 16 gives a diagrammatic view of the stigmatic apparatus open and closed in a species of *Trichodectes*. It will be seen that a long narrow rigidly chitinous bulla follows the wider vestibule, the inner narrow end of which is directly continuous with the extremely narrow initial portion of the stigmatic trachea. This inner end serves as a fulcrum for the closing lever, which in the open position stands at right angles to the trachea, closely apposed to the bulla. From the distal end of this tab a muscle runs to be inserted into the integument alongside the vestibular rim. On contraction of this occluding muscle the tab is revolved through an angle of about 45°, and kinks the elastic trachea against the rigid inner end of the bulla, thus effectually cutting off the air. This form is best observed in the abdominal stigmata of *Trichodectes* and *Gyropus*, the prothoracic stigmata being more complex.

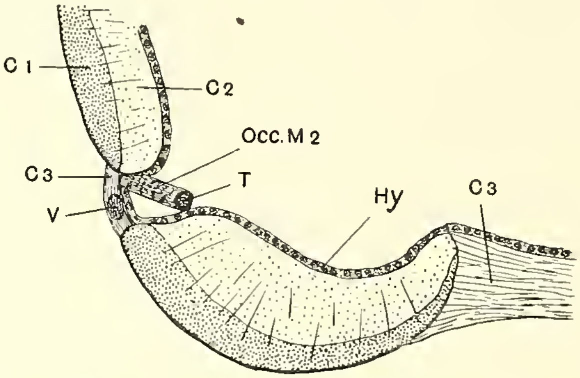


Fig. 17. Part of first of two consecutive sections through an abdominal stigma of *Philopterus bisignatus.*

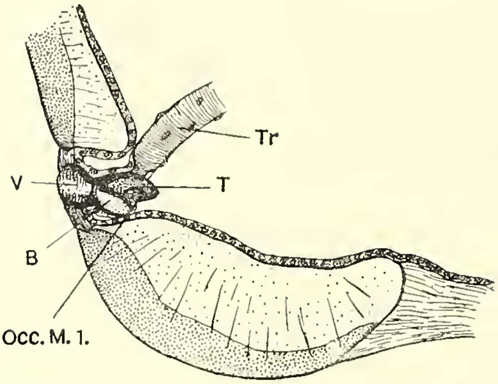


Fig. 18. Part of second of two consecutive sections through an abdominal stigma of *Philopterus bisignatus.*

The second type is illustrated in Figs. 17 and 18, which represent a part of two successive transverse sections through the abdomen of

Philopterus bisignatus. Fig. 17 passes just in front of a stigmatic orifice. It will be seen that the pustulose area round the stigma is composed of a thin laminate cuticle (*C* 3) differing in structure from, and many times less thick than, the chitin immediately surrounding it. The latter is homogeneous, the outer part (*C* 1) deeply coloured, the inner (*C* 2) translucent. Within the pustulose area the section has just sliced the edge of the vestibule (*V*). It will be noticed that the hypodermis (*Hy*) is pushed out into a cylindrical pocket under the stigma. The apex of the chitinous tab (*T*) has been cut off by the section, and running from it to be inserted into the body wall on the inner circumference of the pustulose area is the *extrinsic occlusor muscle* (*Occ. M* 2). The next section (Fig. 18; the figure is slightly schematised, and shows more of the bulla than actually appears in the section) shows the continuation of the chitinous tab (*T*), which rests upon the heavily chitinised walls of both vestibule and bulla. The heavy framework shown on the upper side of the vestibule (*V*) is continued round the bulla (*B*) on the side opposite the tab. A short intrinsic muscle (*Occ. M* 1) runs from the tab to be inserted into this framework, which may be looked upon as the closing bow.

The actual closing of the trachea is brought about at the junction between the bulla and the narrow initial part of the stigmatic trachea. By the simultaneous contraction of both extrinsic and intrinsic occlusors the tab is rotated inwards and forwards so that the knob-like process on its proximal surface (which apparently represents the closing piece of the typical apparatus) is brought directly over the narrow tracheal channel, and is depressed so that the thin elastic dorsal wall is closely apposed to the more heavily chitinous ventral wall. This seems to me the most reasonable explanation of the observed facts; but they are, of course, capable of other interpretation. I assume that the trachea reopens of its own elasticity when the muscles are relaxed. It may be that occlusion is completely brought about by the intrinsic muscle, and that the extrinsic muscle reopens by exerting a leverage on the tab against the fulcrum afforded by the opposite end of the closing bow.

This type seems to be common to all Ischnocera, and is, I believe, present in the same or a slightly modified form in many Amblycera. An intermediate type seems to be present in *Heterodoxus* (Fig. 19), the figure being drawn from a potash-cleared mount; but I have been unable either by dissection or by the examination of several series of sections to convince myself as to the relations of the occluding muscle or muscles.

An examination of the literature concerning the occluding apparatus shows that the subject is still in a state of considerable confusion. Mjöberg (1910, p. 220) figures the occluding apparatus of *Phthirus pubis* (Anoplura) after Landois (1864), with a single extrinsic occlusor muscle; and gives original figures (*l.c.*, p. 221) of the same apparatus in *Haematopinus suis* (Anoplura) and *Gyropus ovalis* on the same plan. But Krancher (1881) had already figured *Haematopinus suis* with an intrinsic muscle only. Solowiow (1909), whose work I have only seen in summarised form, criticises the results of both Landois and Krancher; and finds, in lepidopterous forms, a third muscle present, the so-called *musculus Versoni* first indicated by Verson in *Bombyx mori*. This muscle I do not find in either Mallophaga or Anoplura. The remaining two, the *musculus constrictor* and *musculus tendinosus*, have somewhat similar relations to those which I describe, but I refrain from actually homologising them. Landois and Thelen (1867) figure an orthopterous stigma with an intrinsic occlusor, and with a second muscle arising from the point at which this is inserted into the closing bow, the other insertion not being given. This structure does not in any way resemble the arrangement found in Mallophaga. Finally Mammen (1912), after a detailed description of the stigmata in Heteroptera and Homoptera, summarises insect stigmata into four groups, according as they possess one extrinsic, one intrinsic, two, or three muscles concerned in closing the trachea. The simple type of Mallophagan apparatus would fall into the second division of his first group, that in which a single

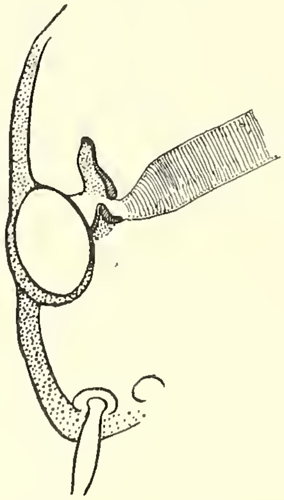


Fig. 19. Abdominal stigma of *Heterodoxus longitarsus* in optical section.

muscle passes from lever to integument; where it would find itself in company with *Geocores*, and the Homoptera. The more complex type, on the other hand, would be placed in the second division of his third group, forms with an extrinsic and an intrinsic muscle, including *Periplaneta* and *Chrysopa*. In the absence of sufficient data for sound comparative statement, the occluding apparatus in Mallophaga cannot at present be said to help towards establishing the affinities of the group.

THE TRACHEAE.

In all forms the main trunks are two in number, and run the full length of the insect, one on either side of the body, from head to hind abdomen. Usually each of these trunks lies about a fifth of the body width from the lateral margin, but in most Goniodidae and Trichodectidae they are much nearer to the mid-line. They may have the appearance of a series of loops between the abdominal stigmata, as in most AMBLYCERA; or they may form straight trunks as in *Tetrophthalmus*, *Heterodoxus*, and most Philopteridae and Lipeuridae. They vary considerably in diameter, as the following table shows.

GREATEST DIAMETER, IN MILLIMETRES, OF TRACHEAL TRUNKS.

Gliricola gracilis	0·005	*Lipeurus crassus*	0·011
Degeeriella cingulata	0·006	*Goniocotes gigas*	0·011
Philopterus occidentalis	0·006	*Trichodectes setosus*	0·014
Goniocotes fissus	0·007	*Docophoroides brevis*	0·017
Lipeurus absitus	0·007	*Lipeurus ferox*	0·030
Gyropus ovalis	0·008	*Heterodoxus longitarsus*	0·039
Aptericola gadowi	0·008	*Laemobothrium circi*	0·069
Lipeurus mutabilis	0·010	*Tetrophthalmus titan*	0·119

The most remarkable feature the table shows is the large size of the trunks in *Heterodoxus* and *Tetrophthalmus*. *Heterodoxus*, in common with other Boopidae, has large stigmata and tracheae, very like those of the Anoplura; and the main trunks are continuous as a posterior commissure, a characteristically Anopluran feature. This resemblance will be discussed further below. With regard to *Tetrophthalmus*, the enormous tracheae are probably a direct adaptation to the habits of the insect, which frequents the gular pouch of pelicans, where it must often be submerged for considerable periods while the host is feeding. Other than these enlarged trunks in *Tetrophthalmus*, no tracheal dilatations or air-sacs occur in any form which I have examined.

The posterior commissure described above for *Heterodoxus* is also present in *Trimenopon*, *Nesiotinus*, and some species of *Trichodectes*; and is figured by Mjöberg (1910, p. 218) for *Eutrichophilus*. It may be present in *Trichodectes setosus*, which Neumann (1913, p. 623) claims to be identical with Mjöberg's species of *Eutrichophilus*, but I have not been able to make it out in ordinary preparations. It is of the same diameter as the main trunks, thus differing from the neural commissures, which are distinctly narrower. Its presence in so many genera that otherwise exhibit primitive characters, as well as its universal occurrence in the Anoplura, leads me to look upon it as a primitive character also. It is not found in the more specialised genera.

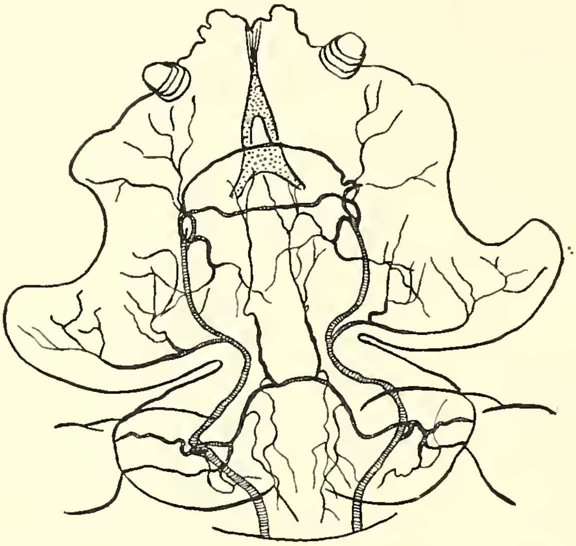


Fig. 20. Prothorax and head of *Gyropus ovalis*, to show superficial ventral tracheae.

Tetrophthalmus is remarkable for having a broad commissure in the fourth segment; but this is not worth stressing, as it is probably directly connected with the very extraordinary change in habit of the species of the genus.

In all species of which I have examined fresh material, I find a great constancy in the arrangement of the whole tracheal system. The four neural commissures are always present; as are the prothoracic triangles; and the chief variations are only in detail of the dorsal and ventral system of branches. *Gyropus* and *Gliricola* have alone afforded exceptions. Fig. 20 shows the ventral superficial tracheae of *G. ovalis*, from which it will be seen that there are two head commissures, and that two long branches run forwards from the prothoracic commissure into the head, extending beyond the brain. *Gliricola* also has two head commissures.

All parts of the body are profusely supplied with tracheal branches, which ramify through the fat-body and muscles, are thickly applied to the alimentary canal throughout its length, and to the internal genitalia, and which are especially abundant about the nerve ganglia. I cannot find in sections any trace of tracheal tubes actually entering into the ganglia, but they are closely and thickly applied to the whole surface. Fig. 21 is a *camera* drawing of the ventral surface of the metathoracic ganglion of *Goniodes piageti*, showing the neural commissure lying across it, and the extraordinary number of branches applied to the surface. These are not so numerous on the other ganglia, so I conclude that the metabolism must be more active here, as the ganglion innervates about three-quarters of the body, while the remaining quarter has four ganglia at its service.

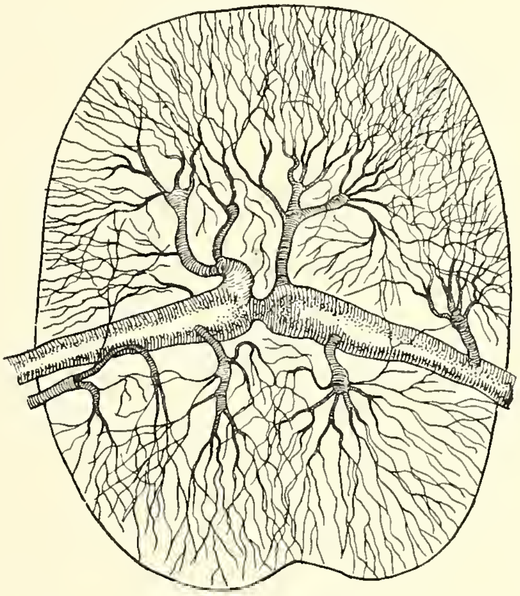


Fig. 21. Ventral view of metathoracic ganglion of *Goniodes piageti*, to show tracheal supply.

The minute structure of the tracheal tubes agrees with that of insects in general. Each consists of a chitinous lining secreted by a cellular layer which is continuous with the reflected hypodermis. The nuclei of this layer can be seen (Fig. 18, *Tr*) easily enough, but I cannot make out any cell boundaries, and the membrane is of a thickness hardly measurable except where a nucleus occurs. In specimens that have been heated in potash till the soft parts were destroyed, and dehydrated in glacial acetic acid, the latter causes the taenidia to swell and burst the chitinous lining. They then tend to uncoil, and their arrangement may be observed. I have noticed in a dissected preparation of *Docophoroides* that the main trunk is composed, not of a single thread wound spirally, but of a band of five. The taenidia are continuous throughout several complete turns, but it is easy to observe their tapering ends in the larger forms.

I have made no mention of the mechanism of respiration, as I have not made any direct observations upon it. The usual dorsiventral depressor muscles exist, and it is probable that air is expelled from the tracheal system by the contraction of these, and re-enters on their relaxation.

COMPARATIVE NOTES AND THEORETICAL CONSIDERATIONS.

I have made some comparison of the respiratory system of Mallophaga with that of the Anoplura and the wingless Copeognatha, the two groups with which a gradually accumulating body of evidence indicates their close affinity. Mjöberg (1910, p. 222) has already pointed out the general agreement between Mallophaga and Anoplura. The latter have fourteen pairs of stigmata in all the forms I have examined. Of these the thoracic stigmata usually overlie the mesothoracic legs, but are often situated between the two anterior pairs. In any case the imperfectly divided thorax of the lice prevents much significance being attached to this difference, if difference it be. The abdominal stigmata are typically on segments 3–8, though in some cases reduction of the first segment makes it appear that the first abdominal spiracles open upon the second and not the third segment. The structure of the stigmata closely corresponds with that of the simpler Mallophagan type. The tracheal vessels show the same general distribution in two main trunks, with stigmatic branches, thoracic triangles, a posterior commissure, and in some cases at least (e.g. *Haematopinus equi* and *Polyplax*) with neural commissures anteriorly. This agreement is so strong that it is difficult to believe it can have any other cause than common derivation.

With regard to the Psocids, I have examined some undetermined wingless Atropidae, and find a broad agreement, though details differ.

There are seven pairs of stigmata, one thoracic, and six abdominal. Here again the reduction of the anterior segments of the abdomen is very marked. Two very short first segments each have well-marked stigmatic branches, but no stigmata, the latter lying, as in both the previous groups, typically in segments 3–8. The general arrangement of the main tracheal trunks, stigmatic branches and dorsal and ventral supply is on a similar plan to that of the Mallophaga; though the stigmatic branches usually form a plexus of two or three vessels with numerous anastomoses, in place of a single branch, and there are other differences in detail.

This brief statement is enough to justify the conclusion that the respiratory system in Mallophaga, Anoplura, and Copeognatha, exhibits a remarkable correspondence. In all three groups there are one pair of thoracic and six pairs of abdominal stigmata, the latter typically on segments 3–8. In all three groups there is evidence, in the shape of vestigial stigmatic branches, of the existence in past time of two additional pairs of abdominal stigmata; and in all three groups there is evidence pointing to the total or partial suppression of one or two of the anterior abdominal segments.

The comparative literature on the number and position of insect stigmata is not sufficiently definite to allow of any positive statement as to affinity indicated by this common possession of the three groups mentioned above. But I consider the relationship of Mallophaga and Anoplura to be definitely established; and as the latter are still usually included among the Hemiptera on account of their sucking mouthparts, and as we have a definite pronouncement on the number and position of the stigmata in this order, it may be useful to emphasise the essential difference between Hemiptera and Anoplura in this regard. Handlirsch (1899) gives the stigmata in Hemiptera as ten pairs, two thoracic on the two posterior segments, and eight abdominal on the first eight segments. He expressly points out that the Anoplura do not conform to this type. In his own words: "Nur die durche ihre eminent parasitische Lebensweise stark modifizierte, vollkommen flügellose Gruppe der Pediculiden (excl. Mallophaga) weicht stärker von dem Grundtypus ab indem bei ihr ausser den zwei ersten abdominalen Stigmenpaaren auch jenes des Metathorax verschwunden ist." As no reason is advanced to connect specialisation following on a parasitic mode of life with an alteration in the number and position of the stigmata which, though it may possess morphological significance, can make little practical difference to the respiration of the group, it seems more reasonable to conclude that this divergence implies a separate origin.

Packard (1874) gives the primitive number of spiracles in winged insects as twelve pairs. Neglecting the Anoplura and Copeognatha, although they are pretty certainly entitled to the same interpretation, it will be seen that seven of these survive in most Mallophaga, the posterior two pairs of the thorax and the anterior two pairs of the abdomen having disappeared, with, presumably, that of the ninth abdominal segment. This allows a generalisation which should be of frequent use in determining the number and disposition of the abdominal segments in Mallophaga, namely that the sixth pair of abdominal spiracles occurs on what is morphologically the eighth segment, though in the Boopidae, Ricinidae, and *Gyropus* of the Amblycera, and in the whole of the Ischnocera, this segment is apparently the seventh. Again certain post-embryonic stages in both Ischnocera and Amblycera show ten apparent abdominal segments, which become reduced to an apparent nine in the adult. In particular species of *Lipeurus* from petrels illustrate this condition. Kellogg (1896) has described as species two forms which he calls *L. diversus* and *L. limitatus*. The former has nine segments, the latter ten. But the latter is the young of the former. Similarly Taschenberg (1882) has described *L. fuliginosus* with nine segments, and *L. testaceus* with ten. The latter is not, in this case, the young of the former, but is the immature form of a species of the same type, for which the name will stand. In these, as in other examples that might be quoted, the last ecdysis changes the three terminal segments of the abdomen into an apparent two. The segments in question come after the last which bears spiracles, so we can thus state that the maximum number of segments in the abdomen of Mallophaga is eleven, though this number is not found in any adult. This statement, of course, involves the assumption that an anterior segment of the abdomen in the Ischnocera has become incorporated with the thorax, or suppressed. We may assume this by analogy with what has been pointed out for the Amblycera above; but, in addition, the condition in *Trichodectes* offers very strong support. In *T. longicornis*, for example, I find interpolated between metathorax and first abdominal tergite a rudimentary tergite which does not reach the lateral margins, but which bears a transverse band bordered posteriorly by a row of six hairs. In *T. divaricatus* a similar rudimentary tergite is very surely present, but is uncoloured and without hairs. In *T. setosus*, on the other hand, there is no trace of this tergite.

Taxonomic Value.

The general constancy of the respiratory system in Mallophaga seems to me a good argument for allowing a fair amount of importance to such differences as occur. The points on which I lay stress are primarily the number of pairs of stigmata in the abdomen, together with their distribution on the abdominal segments; and, in the second place, the presence or absence of a posterior commissure. This commissure when present is equal in calibre to the main trunks, and justifies the description of those forms which possess it as having a single continuous tracheal trunk, rather than two separate sub-parallel trunks.

On the basis of the respiratory system, the Amblycera fall into seven groups:

A.	With five pairs of abdominal stigmata (3–7) and a posterior commissure	*Trimenopon* (*Philandesia?*)
B.	With six pairs of abdominal stigmata (2–7) and a posterior commissure .	Fam. Boopidae
C.	With five pairs of abdominal stigmata (3–7), no posterior commissure, and two head commissures . . .	*Gliricola*
D.	With six pairs of abdominal stigmata (2–7), no posterior commissure, and two head commissures . .	Fam. Gyropidae (excl. *Gliricola*)
E.	With six pairs of abdominal stigmata (2–7) and only the usual four neural commissures . . .	Fam. Ricinidae
F.	With six pairs of abdominal stigmata (3–8) and only the usual four neural commissures	Fams. Menoponidae, Laemobothriidae, Ancistronidae
G.	With six pairs of abdominal stigmata (3–8), the usual four neural commissures, and a transverse commissure in the fourth segment .	*Tetrophthalmus*

Of these Group A is undoubtedly of family rank, *Trimenopon* occupying a very isolated position. It shows a superficial resemblance to the Boopidae, but is without the accessory sac in the ♂ genitalia and the special sensory organs of the first three abdominal segments which characterise that family. In addition it exhibits a fusion of prothorax and mesothorax, a condition not seen elsewhere in the Mallophaga. *Trimenopon* must rank as the type genus of a family Trimenoponidae. *Philandesia*, which I have not had an opportunity to examine, probably belongs here also.

Group B has already been accorded family rank by Mjöberg (1910) on an examination of one species of *Boopia*. After examining a considerable number of species of *Boopia* and *Heterodoxus*, and two of *Latumcephalum*, I agree that the Boopidae hold a very distinct position.

Groups C and D, despite the difference in number of the stigmata, I leave for the present in the family Gyropidae, which was established by Kellogg (1896). But this difference further justifies Mjöberg (1910) in establishing a separate genus for *G. gracilis*; though this separation has not, apparently, been recognised by some later writers (Neumann, 1912; Kellogg and Nakayama, 1914). I have not handled sufficient material of this family to venture any interference; but I think it will possibly be found that there is less uniformity among the species than is commonly supposed.

Group E has already been accorded family rank by Mjöberg (1910) under the name of Physostomidae. As Neumann (1906) has pointed out that *Physostomum*, Nitzsch is a synonym of *Ricinus*, de Geer; and Johnston and myself (1911) that the family name Ricinidae must replace that of Liotheidae; it follows that this family, though now limited to two genera, must retain the name Ricinidae.

Group F includes most of the remaining AMBLYCERA. Mjöberg (1910) has established two families, Menoponidae, including a number of genera, and Laemobothriidae with a single genus. Of those genera not specifically mentioned by Mjöberg probably all may safely remain in the family Menoponidae with the exception of *Ancistrona*, which, on the structure of the lateral region of the head and antennary fossa, is quite as distinct as *Laemobothrium*, and is certainly entitled to family rank. There will thus be three families in the group, Menoponidae, Laemobothriidae, and Ancistronidae, towards the separation of which the respiratory system gives no help.

Finally Group G includes the single genus *Tetrophthalmus*, and is only distinguished from the last by the transverse commissure of the fourth segment. In view of the enormous development of the tracheal trunks in connection with a change of habit such as we have not previously had to take into account, this is best looked upon as a correlated adaptation. The presence of combs upon femora and abdomen shows that the affinities of the genus lie with *Colpocephalum* rather than with *Menopon*, with which it was for so long associated; but the genus may remain in the Menoponidae.

Turning to the ISCHNOCERA, we find the stigmata are uniform throughout the group, and the only difference of any importance is the occurrence of the posterior commissure in *Nesiotinus* and some species of *Trichodectes*.

Kellogg (1903) has already pointed to the fact that *Nesiotinus* possesses both Ischnoceran and Amblyceran characters. The additional evidence afforded by the primitive tracheal arrangement indicates that it must certainly be looked upon as a very primitive Ischnoceran form; and also that it must, as I have previously suggested (1915, p. 384), form the type genus of a family Nesiotinidae.

The Trichodectidae require further examination. Stobbe (1913, 1913*a*) has recently revised the family, and established two new genera, but on the same somewhat superficial grounds that have proved such a stumbling-block to a proper understanding of Mallophaga in the past. From the variations I have noticed in some twenty species which I have had under my eyes, variations which include the presence or absence of a vestigial segment in front of the abdomen, and of a posterior commissure; the possession of three, four, or five antennal joints; the presence, in one species at least, of only five pairs of abdominal stigmata; and the very variable structure of the hind-abdomen and ♂ genitalia, I am convinced that this apparently homogeneous group is capable of being split up upon sound lines, and that a comparative study of the tracheal and stigmatal arrangement will considerably assist such division. Such a task must, however, be left to some worker with a far more considerable material at his disposal than is available to me.

The remaining six families of the ISCHNOCERA (Lipeuridae, Docophoroididae, Goniodidae, Philopteridae, Giebeliidae, Akidoproctidae) show such uniformity in their tracheal systems that nothing of help in taxonomy can be gained from a study of the respiratory apparatus.

CONCLUSIONS.

The results of this study may be briefly summarised as follows: The tracheal system of Mallophaga is disposed in two main trunks, with stigmatic, dorsal, and ventral branches, with four narrow commissures (*neural commissures*) in connection with the main nerve masses, and with, in primitive forms, a posterior abdominal commissure.

The stigmata are typically fourteen in number, one pair prothoracic, and six pairs abdominal, usually dorsal, typically on segments 3–8. At least two types of occluding apparatus are present.

In the structure and relations of the respiratory system the Mallophaga agree very closely with the Anoplura, and also, in a more general way, with the wingless Copeognatha.

As the respiratory system is very uniform, such variations as do occur have some taxonomic importance, and have served to emphasise some divisions already made, and to establish new divisions.

REFERENCES.

FULMEK (1907). Die Mallophagen—Ein Sammelbericht mit eigenen Beiträgen. *Mitteil. d. Naturw. Vereins d. Univ. Wien*, v.

HANDLIRSCH (1899). Wie viele Stigmen haben die Rhynchoten? *Verh. d. K. K. Zool.-Botan. Ges.*, Wien.

HARRISON (1915). On a new family and five new genera of Mallophaga. *Parasitology*, VII, No. 4.

JOHNSTON and HARRISON (1911). Notes on some Mallophagan generic names. *Proc. Linn. Soc. N. S. Wales*, XXXVI.

KELLOGG (1896). New Mallophaga, I. *Contrib. to Biology from Hopkins' Seaside Laboratory*, IV.

KELLOGG (1903). Two new genera of Mallophaga. *Biol. Bull.*, v.

KELLOGG and NAKAYAMA (1914). Mallophaga of the Vizcacha. *Ent. News*, XXV.

KRANCHER (1881). Der Bau der Stigmen bei den Insekten. *Zeitschr. wiss. Zool.*, XXXV.

LANDOIS (1864). Anatomie des *Phthirius inguinalis* Leach. *Zeitschr. wiss. Zool.*, XIV.

LANDOIS and THELEN (1867). Der Tracheenverschluss bei den Insekten. *Zeitschr. wiss. Zool.*, XVII.

MAMMEN (1912). Über die Morphologie der Heteropteren- und Homopterenstigmen. *Zool. Jahrb.*, Abt. f. Anat., XXXIV.

MJÖBERG (1910). Studien über Mallophagen und Anopluren. *Arkiv f. Zool.* VI.

NEUMANN (1906). Note sur les mallophages. *Bull. Soc. Zool. France*, XXXI.

NEUMANN (1912). Sur le genre *Gyropus* Nitzsch. *Bull. Soc. Zool. France*, XXXVII.

NEUMANN (1913). Notes sur les Mallophages, III. *Arch. de Parasitologie*, XV.

PACKARD (1874). On the distribution and primitive number of spiracles in insects. *Amer. Naturalist*, VIII.

SHIPLEY (1909). The ecto-parasites of the red grouse. *Proc. Zool. Soc. London.*

SNODGRASS (1899). The anatomy of the Mallophaga. *Occ. Papers Cal. Acad. Sci.*, VI.

SOLOWIOW (1909). Zum Bau des Verschlussapparates der Stigmen bei den Insekten. Summary in *Zool. Anzeiger*, XXXIV.

STOBBE (1913). Mallophagen. 1–2 Beitrag: Neue Formen von Säugetieren. *Entom. Rundsch. Jahrg.*, XXX.

STOBBE (1913 *a*). Mallophagen. 3 Beitrag: Die Trichodectiden des Berliner Museums für Naturkunde. *Sitzungsber. Ges. Natforsch. Freunde.*

TASCHENBERG (1882). Die Mallophagen. *Nova Acta*, Halle, XLIV.

ON THE NATURAL OCCURRENCE OF HERPETOMONADS (LEPTOMONADS) IN MICE.

By H. B. FANTHAM, M.A., D.Sc.,

Christ's College, Cambridge, and Liverpool School of Tropical Medicine,

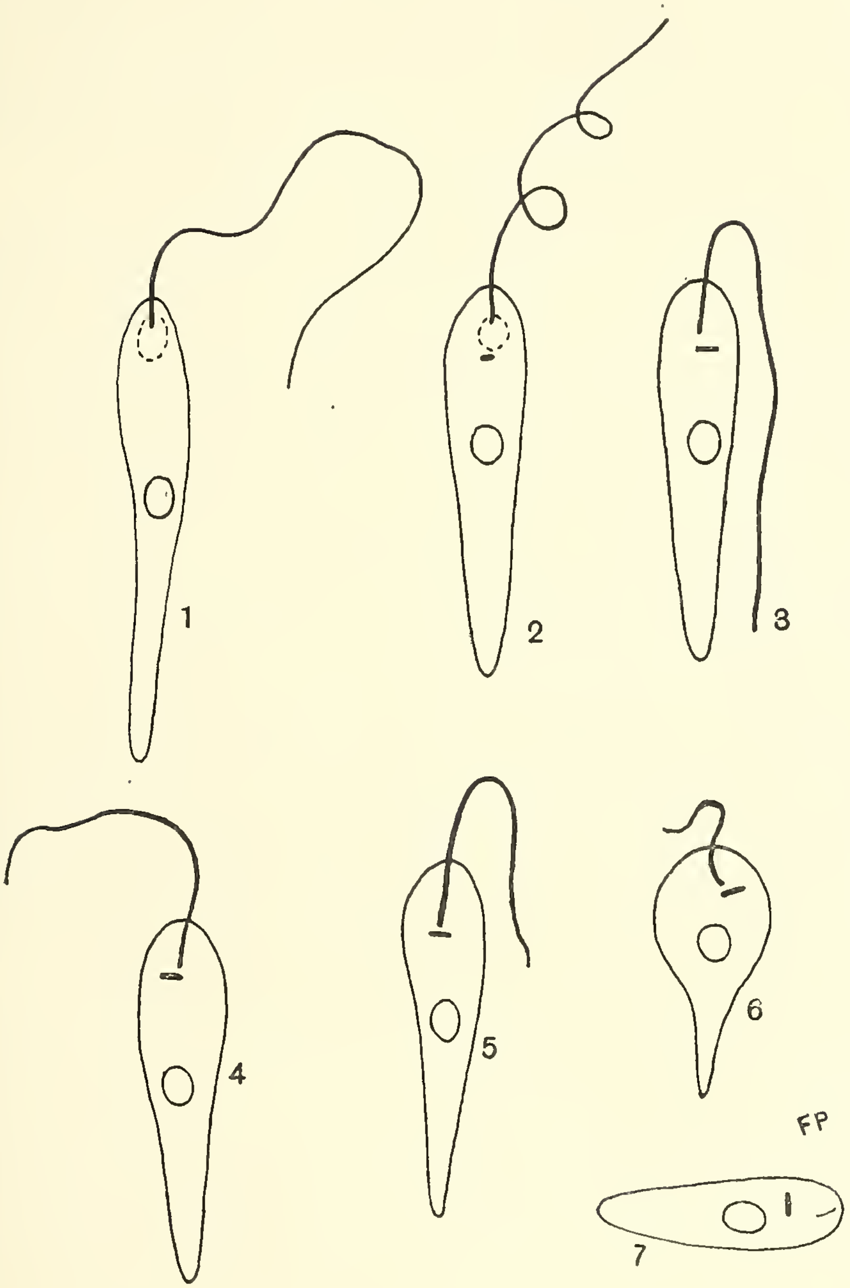
and ANNIE PORTER, D.Sc., F.L.S.,

Beit Memorial Research Fellow, Quick Laboratory, University of Cambridge.

(With 7 Text-figures.)

While engaged in experimental researches on the introduction of insect flagellates, belonging to the genera *Herpetomonas* and *Crithidia*, into vertebrates, we have recalled to mind some former observations of ours made in 1909. When examining the blood of mice artificially infected with the spirochaetes of relapsing fever in the Quick Laboratory, Cambridge, we observed flagellates in the peripheral blood of the mice. These flagellates, which were scanty, were studied in fresh preparations by us and drawings of the organism were made with the camera lucida. Some of these drawings are now reproduced, together with others made by us subsequently. The flagellates were also observed by Professor Nuttall and his laboratory assistant, Mr B. G. Clarke, and we were unanimously agreed that the flagellates belonged to the genus *Herpetomonas*, or *Leptomonas* as some have since preferred to call it. The significance of the presence of herpetomonads in the blood of mice was very puzzling at the time, and pressure of other work prevented the subject being followed up. During 1911 and 1912, these flagellate organisms have been seen by all of us, but they were always evanescent and could not be found in fixed and stained preparations. The parasites were seen on different occasions in three mice altogether.

The Protozoön presented the typical aspect of a herpetomonad and was uniflagellate. The flagellar end was rounded and the body gradually



Herpetomonas pattoni found in the blood of mice. Organisms stained *intra vitam.*

Figs. 1–5. Flagellate forms.

Figs. 6, 7. Parasites approaching the non-flagellate stage, and tending to become leishmaniform. ×3000 approximately.

tapered to the opposite or posterior end which was often pointed (Figs. 1–5). The movements of the organism were very active and jerky. Violent contraction of the body together with vigorous lashing of the flagellum could occur. The flagellum was relatively rigid at its basal end near the body, the rest lashed freely and spiral coilings of the flagellum were frequently seen, while backward bending was sometimes noticed. The flagellum functioned as a tractellum, as it dragged the body after it. There was no undulating membrane.

The bodies of the flagellates were 11μ to 18μ long and about 3μ to 4μ broad at the widest part. The flagellum was about equal to or slightly greater than the body in length. The nucleus, as seen by *intra vitam* staining, was approximately centrally situated. The blepharoplast was refractile and often barlike in life. Anteriorly a refractile area was sometimes present, which was apparently the flagellar sac of some authors, the flagellum seeming to be partially retracted into it at times.

Partial formation of the non-flagellate stage of the parasite was sometimes observed. Regression of the flagellum accompanied by cytoplasmic concentration resulted in the assumption of an elongate oval resting form (Figs. 6, 7).

It may be added that no especial ectoparasites were found on the mice, but they were kept in laboratories where rats and rat-fleas, *Ceratophyllus fasciatus* and *Ctenophthalmus agyrtes*, were also present. The latter fleas came of a stock known to be infected with *Crithidia ctenophthalmi*. It is very likely that the former flea was infected with *Herpetomonas pattoni*, as such fleas in England are known to harbour scanty infections of this parasite. The non-flagellate stages of *Crithidia* and *Herpetomonas* are indistinguishable.

We have succeeded in introducing *Herpetomonas jaculum*, *H. pediculi*, *H. ctenophthalmi*, and *Crithidia gerridis* into vertebrates such as mice and dogs by feeding or inoculation. We have also shown that cold blooded vertebrates like sticklebacks, frogs, toads, lizards and snakes can be infected with these insect flagellates. These results are recorded in two papers read before the Cambridge Philosophical Society on November 23rd, 1914, and May 10th, 1915. Thus we see that what can be induced artificially in the laboratory can occur also in Nature.

Since the above observations were made, one of us, while working in Liverpool, has been much interested in some remarks by Dutton and Todd (1903) relating to researches made in 1902 on the Gambia. These workers record the presence of *Herpetomonas* in the blood of house mice. Unfortunately, these important remarks appear to have been overlooked and the surviving author has since changed his views. We have no doubt in our own minds, from the description given, that the flagellates seen in the Gambia were herpetomonads. However, the matter is so important that the original statement of Dutton and Todd is reprinted in full.

"FLAGELLATA IN THE BLOOD OF A MOUSE.

At McCarthy Island we obtained a few house mice and some field mice (Spec. unknown).

Fourteen of the former in all were examined, and in the blood of three flagellated protozoa were seen. Twenty field mice were examined, but none were found to be infected. The organism occurred infrequently in the blood of the mice infected, and we never saw more than one or two parasites in a fresh coverslip preparation.

The organism was striking, in that it presented characteristics which differentiated it, at a glance, from a trypanosome. It consisted of a long oval-shaped body with blunt rounded ends, to one of which a very long flagellum was attached. At this end the body tapered slightly. A glance showed that the long flagellum, slightly longer than the body, was the chief organ of locomotion. It acted as a tractellum, and obviously dragged the body of the parasite after it. On encountering an obstruction the flagellum lashed out in all directions, hurled the red cells behind it, and often twisted round, so that its tip reached past the posterior end of the body. On these occasions, it was easy to examine the structure and measure the length of the parasite, as the body was perfectly quiescent. The protoplasm has a slightly granular appearance and in its substance, placed a little in front of the centre and towards the flagellated end, is a collection of refractile granules. About 5μ from the anterior end is seen a highly refractile spot from which the flagellum takes origin. No suggestion of an undulatory membrane was seen. The length of the body in the living condition is $20{\cdot}8\mu$, and its greatest width $3{\cdot}2\mu$. The body of the parasite sometimes assumes an 'S'-shaped form, on account of external pressure or rapid changes of direction of movement, but no active contractions of the protoplasm were seen.

Unfortunately, two mice sent home infected with this parasite died on the voyage, and in the films made from the mice while in Gambia, no specimens have been seen. A small rat inoculated from one of the mice has not shown the parasite in its blood. No symptoms were observed in the mice infected.

This parasite resembles very closely *Herpetomonas* (*Leptomonas*) *Butschli* (S. Kent). The figures given of this organism correspond very closely with our flagellate, except that in the mouse parasite there is not the marked tapering of the non-flagellated end of the body. *Herpetomonas Butschli*, however, inhabits the intestinal tract of *Trilobus Gracilis*, and not a vertebrate circulatory system."

Considering these facts, it appears to us that the following conclusions are warranted:

(1) That natural herpetomonads (or leptomonads) occur in mice.

(2) That the origin of the infection is to be sought in a flagellate of an ectoparasite of the mouse. This flagellate is very probably *Herpetomonas pattoni*, a natural or specific parasite of fleas (especially rat fleas), which protozoön can adapt itself to life in the blood of mice.

(3) Herpetomonads have been recorded from rat fleas, dog fleas and human fleas. Probably the flagellates are varieties of one species, *H. pattoni*, which can live in the blood and certain internal organs of rats, mice, dogs and man.

REFERENCES.

Dutton, J. E., and Todd, J. L. (1903). "Flagellata in the blood of a mouse," being part of Sect. vii of the First Report of the Trypanosomiasis Expedition to Senegambia (1902). *Liverpool Sch. Trop. Med., Memoir XI*, pp. 56, 57.

Fantham, H. B., and Porter, A. (1914–1915). Some Insect Flagellates introduced into Vertebrates. *Proc. Camb. Philos. Soc.*, xviii, pp. 39–50. 1 Plate.

Fantham, H. B., and Porter, A. (1915). Further Experimental Researches on Insect Flagellates introduced into Vertebrates. *Proc. Camb. Philos. Soc.*, xviii, pp. 137–148. See also *Cambridge Univ. Reporter*, xlv, p. 323 (Dec. 1, 1914) and xlv, p. 931 (May 26, 1915).

A REPORT ON RESEARCHES ON SPRUE IN CEYLON

1912—1914

By

P. H. BAHR

M.A., M.D., D.T.M. and H. (Cantab.), M.R.C.P. (Lond.), M.R.C.S.
London School of Tropical Medicine
Horton-Smith prizeman, Cambridge, 1914

Large Royal 8vo. pp. x + 156. With 8 plates and a map.
Price 7*s* 6*d* net

The frequent occurrence during recent years of sprue amongst the planting community of Ceylon, together with the lack of trustworthy information on the subject, made it advisable, from an economic, as well as from a humanitarian point of view, that the subject should be investigated in the light of modern research. At the request of the government of Ceylon, therefore, the London School of Tropical Medicine appointed Dr Bahr to undertake such an investigation and in these pages he has recorded the results of his efforts to unravel the etiology of one of the least understood, but nevertheless one of the most insidious diseases known to Tropical Medicine.

CAMBRIDGE UNIVERSITY PRESS, FETTER LANE, LONDON
C. F. CLAY, Manager

THE JOURNAL OF ECONOMIC BIOLOGY

Edited by

WALTER E. COLLINGE, M.Sc., F.L.S., F.E.S.

Contains articles treating of all branches of Economic Biology, Entomology, Parasitology, Mycology, etc. Fully illustrated by lithographic plates and text figures. A few sets of Vols. 1—9 still remain, price 21*s*. each. Volume 10, now in course of publication, will consist of four parts, price 21*s*.

All editorial communications should be addressed to Walter E. Collinge, 8, Newhall Street, Birmingham, and all subscriptions to

London: DULAU & CO., Ltd., 37, Soho Square, W.
Berlin: R. FRIEDLÄNDER & SOHN.

CONTENTS

(All rights reserved)

PARASITOLOGY is published about four times a year. The numbers afterwards are issued in volumes each containing four numbers and amounting to between 400 and 500 pages, with plates and figures.

Papers for publication should be sent to Professor Geo. H. F. Nuttall, F.R.S., Longfield, Madingley Road, Cambridge. Other communications should be addressed to the University Press, Cambridge.

Papers forwarded to the Editors for publication are understood to be offered to *PARASITOLOGY* alone, unless the contrary is stated.

Contributors receive seventy-five copies of their papers free. Additional copies, not exceeding 200, may be had at cost price: these should be ordered when the final proof is returned.

The subscription price is £1. 10*s.* per volume (post-free), payable in advance; single numbers 10*s.* net (double number 20*s.* net). *Subscribers to the Journal of Hygiene* may obtain single numbers of *PARASITOLOGY* at the reduced price of 7*s.* 6*d.* net, or may become subscribers at the reduced rate of £1. 1*s.* per volume. Subscriptions may be sent to any Bookseller, or to Mr C. F. CLAY, Manager, Cambridge University Press, Fetter Lane, London, E.C.

The Cambridge University Press has appointed the University of Chicago Press agents for the sale of *Parasitology* in the United States of America and has authorised them to charge the following prices: Subscription $7.50 net per volume; single numbers $2.50 net each, double numbers $5.00 net each. Subscribers to the *Journal of Hygiene* may become subscribers to *Parasitology* at the reduced rate of $5.25 per volume.

The prices of back volumes are as follows:

Volumes I, II, III and IV (1908–11). Each volume in four parts, paper covers, 21*s.* net per volume. Bound in buckram, 25*s.* net per volume.

Volumes V, VI and VII (1912–15). Each volume in four parts, paper covers, 30*s.* net per volume. Bound in buckram, 34*s.* 6*d.* net per volume.

CAMBRIDGE: PRINTED BY JOHN CLAY, M.A. AT THE UNIVERSITY PRESS.